VOLCANOES

AND EARTHQUAKES

A popular account of their nature, causes, effects and geographical distribution, from personal observation in the Hawaiian and Philippine Islands, Japan, Iceland, the Mediterranean Basin, Spain and the United States

BY

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An American in Iceland
and others

"C'est ce que j'ai vu — le temoin au juge" — J BARRANDE

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IN MEMORIAM.

TO

GEORGE MANN CURTIS:

MY COMPANION IN MOST OF THE SCENES HERE DESCRIBED;
WHOSE INEXHAUSTIBLE GOOD NATURE,
WHOSE APPRECIATION OF THE GRAND AND BEAUTIFUL,
AND WHOSE EVER-PRESENT WIT AND REFINEMENT,
MADE HIM A WELCOME GUEST IN MANY LANDS,
THESE PAGES ARE AFFECTIONATELY DEDICATED,

BY THE AUTHOR.

PREFACE.

THE following pages are not intended as a scientific text-book, nor for experts in the difficult and hotly-contested theories of volcanic and earthquake disturbances. They are prepared for popular reading, and seek to give such information on these subjects, now of universal interest, as every liberally educated person may desire to possess.

Much of the material used is the result of my own observation in the countries described, and partakes largely of personal adventure; the remainder is condensed and simplified from special books and journals in many languages. The main idea of the narrative has been to save the reader the time and labor of wading through or skimming over thousands of printed pages scattered over the civilized world during the last half-century; attempting for his mental advantage what the pharmacist does in concentrating his watery decoctions into a solid extract for curative purposes.

I have taken up volcanic countries in the order which seemed best calculated to lead from the simple to the complex, and have grouped under each whatever I had to say about it, without reference to sequence of similar subjects in other chapters. Though this may be deemed objectionable by the scientific reader, I consider it the most desirable way to present to the popular mind the facts of what I name "volcanic geography," and to show that the causes of the earthquake are world-wide.

In the final chapter of each part are given the conclusions, deducible from the preceding ones, which I believe are admitted, by most scientists in both hemispheres, to represent our knowledge up to the present time. These, of course, are liable and even certain to be modified by subsequent investigations.

The illustrations are from photographs and drawings made on the spot, and will render plain many points which words cannot faithfully describe.

A copious index will enable the reader to turn at once to any desired subject.

S. K.

BOSTON, *January*, 1888.

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VOLCANOES AND EARTHQUAKES

CHAPTER I.

LAVAS.

Nature and characters. — Varieties. — Composition. — Movements. — Make a fertile soil.

I DESIRE in this volume to relate my experience in volcanic countries, in the shape of a personal narrative, from notes taken on the spot. In this way the reader may be enabled to form a better idea of the volcanic phenomena, as well as of local peculiarities, and in a far more acceptable and intelligible form than by a didactic treatise. Only the countries that I have visited will be specially described. These, however, comprise Europe, Asia, and the Pacific Islands, and will be sufficient to furnish ample materials for a popular explanation. I do not pretend to settle any of the many disputed points in the geology and physics of the globe; I simply wish to follow the motto of Barrande, placed on the title-page: "C'est ce que j'ai vu — le temoin au juge." In other words, I merely describe what I have seen, and leave the explanation to competent judges.

A few explanatory words relative to the properties and varie-

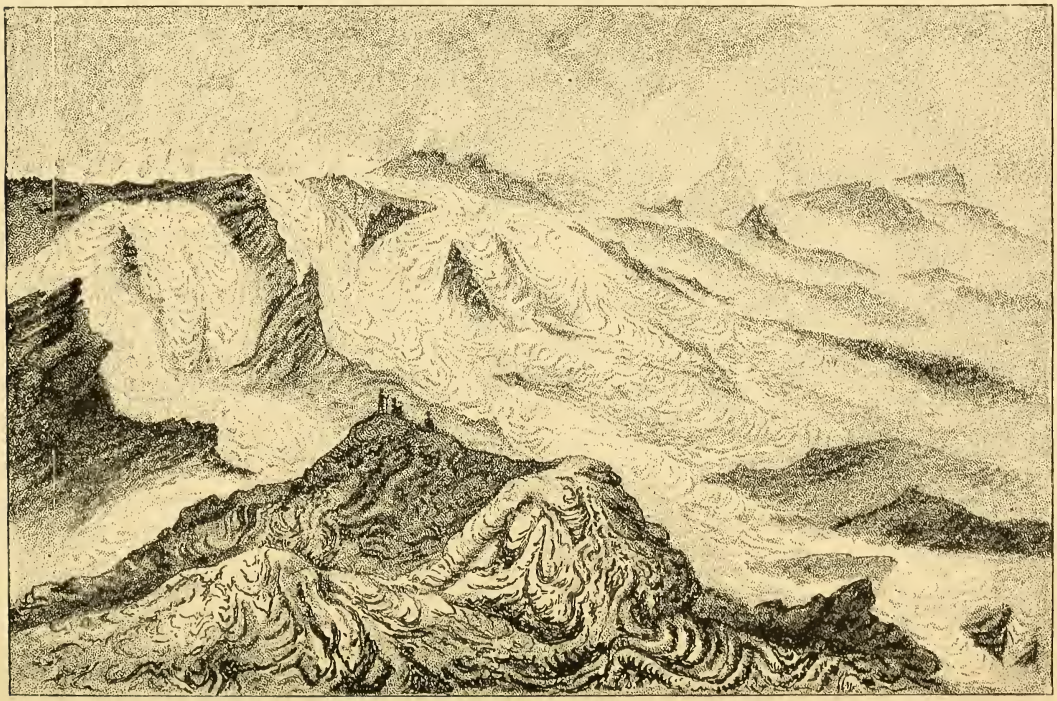
ties of lava seem desirable before proceeding to the detailed narrative.

Lavas are the more or less fluid matters poured out from volcanic vents in a glowing, highly-heated condition derived from melted or softened rocks far below the surface of the earth. They resemble the slags and clinkers around our furnaces and kilns, and, like them, are composed of various stony materials of different degrees of hardness and roughness.

According to Prof. Judd, oxygen constitutes nearly one half the weight of all lavas, combined with other elements in the form of oxides; silicon forms about one quarter, and aluminium one tenth of most lavas; magnesium, calcium, iron, sodium, and potassium, in varying proportions, make up the other materials; silica or silicic acid forms the greater part of their mass: from one half to four fifths; this, acting as an acid, unites with other bases, making silicates. Those having the largest amount of silica are called acid lavas, and those with less silica and more bases, basic lavas: the latter are usually much the darkest in color, and the heaviest, like the basalts; the former being generally comprised under trachytes: as the iron in them escapes, they assume a reddish or brownish tint. Basic lavas are more easily fusible, and, in their natural state, largely crystalline; when subsequently melted they form a glass. When a lava mass cools rapidly near the surface, it becomes a volcanic glass called obsidian; when cooled slowly and at great depths, and under immense pressure, the mass becomes crystalline.

There are three kinds of lava:

I. Smooth, with a glassy crust, which has cooled into all imaginable folded and twisted forms: seen on an immense scale in the bottom of the crater of Kilauea in the Sandwich



A LAVA FLOW.

Islands, where it is known as *pahoehoe.* This is the most common, and occurs when the flow passes over rocks or dry soil at a gentle slope.

II. Scoriaceous or clinker lava, rough and fragmentary, found where the stream has passed through woods, or where its course has been impeded by obstacles or inequalities of the ground, or where the heat causes the explosion of steam in former caverns over which it passes.

III. Spongy lava, whose terrible roughness and hardness must be seen and felt to be appreciated: its jagged mass is broken into needles, ridges and crests, like the surface ice of a glacier, or the slag of a furnace. This appears to occur when the flow meets with an impediment which gives way just as the lava is granulated, rolling the spongy mass over and raising huge piles from which the liquid portion drains away, — where it has very suddenly cooled, — or has been broken up after consolidation by subsequent underground flows. It is not always easy to draw the line between the second and third forms.

Lava is very capricious in its movements: sometimes overwhelming everything, at others turned aside by small obstacles; sometimes forming huge bubbles, which remain as caverns as large as an ordinary room, at others tunnels, bridges, peaks and plateaus; but everywhere, when recent, black, hard, without water, hot from the sun, and indescribably dismal. The decomposed lava, in a temperate and moist climate, makes a fertile soil which is soon overgrown by vegetation; the smooth lava is too hard for plant life except in the cracks.

Lava, wherever occurring, presents the same general characters. I have seen that of the Sandwich Islands boiling in its fury in the Lake of Kilauea, and have travelled over hundreds of

miles of its hardened crust and volcanic sand. From Reykjavik to Thingvalla, and thence to the geysers of Iceland, the scenery is almost entirely of the same character, but doubly desolate and black from the absence of vegetation. I have dodged and afterward collected the fiery bombs from the crater of Vesuvius; I have gathered many specimens from Etna, Fujiyama, the Philippine and Javan archipelagoes; but all present the same general appearances.

I shall briefly state the principal theories of volcanic and earthquake action, with the arguments pro and con, and endeavor to bring some order out of the chaos which seems to exist in the treatises to which non-scientific readers have access in our magazines and public libraries. Any unprejudiced mind, with a fair knowledge of physics and geology, can thus form a satisfactory idea of the grand, but simple, principles which, I believe, underlie these phenomena of world-wide disturbance.

CHAPTER II.

THE HAWAIIAN ISLANDS. — KILAUEA.

Volcanic characters of the group. — A family party. — Honolulu to Hilo. — Ride through a tropical forest. — The Volcano House. — Night scene. — A sulphur bath. — Descent of the crater of Kilauea. — Its situation. — Almost level floor. — Getting warm under foot. — The "lake of fire." — An awful sight. — Volcanic manifestations. — Sketch of its eruptions. — Display in 1840. — The Goddess Pelé.

THE group of the Hawaiian or Sandwich Islands has been produced by volcanic forces. They all present magnificent proofs of the intensity of these forces in past ages; and from the moment of landing in Honolulu, all over the island of Oahu, and in the neighboring islands of Kauai and Maui, the eye can hardly rest on a landscape or a shore which is not the work or the modification of lava streams. Yet as there are except in Hawaii, the largest and most southeasterly of the group, no existing active volcanoes or any tradition of such, it will be best to proceed at once to Kilauea, on the side of Mauna Loa, for the first volcanic experience.

Our family party, three middle-aged gentlemen, old travellers, and two young ladies, set sail for Hilo, Hawaii, the gateway of this volcano. The sea is generally rough in these island channels, and the steamer is small, inconvenient, crowded, and overrun with vermin large and small, creeping and flying, biting and stinging. The most comfortable place, therefore, is on deck, day and night, even in spite of spray and rain.

Lahaina, on the island of Maui, was once an important whaling station, but is now decayed and almost deserted. Touching here to take on passengers, and obtain a supply of delicious grapes, bananas, and other tropical fruits, we stretched across to Hawaii, stopping in Captain Cook's bay and Kona, then passing to the north around the island, and thence south to Hilo.

On the northwest shore of Hawaii are deep ravines with numerous cascades and waterfalls, utilized for sugar and saw mills, and floating logs down the mountains, which have been much changed by the action of the elements; these water-worn valleys are of great depth, often very fertile, and afford some of the wildest and most beautiful scenery in the world. The sea has also modified the coast by its incessant breakers; the shore is generally barren, and so rugged that there may be no landing place for twenty miles. The great volcanoes of Mauna Loa and Mauna Kea, along whose sides we steamed for many hours, rise to a height of fourteen thousand feet. Their immense mass, the product of their many lava flows, has such a gentle slope that one is deceived as to their height; their apparently smooth surfaces, clothed high with vegetation, are in reality much broken and often very difficult of access. The rain, which seems continually falling on their summits, courses down the slopes, wearing away valleys which extend very high up, and are cut by other valleys at right angles, similarly produced. These water-courses reduce the sides in many places to sharp-edged buttresses, which form some of the most characteristic scenery, covered as they are in the older islands, with verdure to the very top.

Starting from Hilo on horseback, with a guide, we found the

first seven miles of the road good, the country fertile, with here and there a thatched house, and now and then a native, but the signs of humanity were few. Arriving at a thick cocoa-nut grove, tenanted by a native family, we saw for the first time the old primitive costume in a venerable man who wished us *aloha:* an untranslatable salutation combining a cheerful good-day and a kind greeting; he offered us water and wished us a pleasant and safe ride through the wilderness of tropical verdure, alternating with barren lava. This native was of the color of mahogany, and was entirely nude except a narrow strip of cloth around the hips; the *malo.* Our native guide was named "Opa," which we anglicized into "Scissors;" he spoke English very well, having served for years on an American whaling ship.

The comfort and convenience of such a trip depend very much on your guide, as you are completely at his mercy; ours was a faithful fellow, who afterward died of leprosy, which is very common in the islands: a fatal, but, it is believed, a non-contagious disease. [I will say here that we met with no attempts at imposition on the part of the natives; for a fair price they always placed at our disposal the products of their taro patches, cocoa-nut groves, and banana plantations.] The vegetation was quite new and characteristic, largely made up of tree-ferns and screw-palms, with intertwining creepers, many with high-colored, but scentless flowers. Of birds we saw none except a few hawk-like owls which prey upon the rats, mice, and lizards; these latter are the only reptiles found on the islands, and are pretty, harmless, lively creatures. The decomposed lava made a very fair road, though here and there were long smooth, glassy stretches crushing under foot like thin ice.

This alternated with miles of rough jagged lava, a scene of utter desolation, reminding one of the slag of a gigantic iron furnace.

At noon we reached the "Half-Way House," a native hut made of grasses, straw and leaves of the screw-palm, where we were surprised to find an old-fashioned four-post bedstead for weary travellers of aristocratic habits who may be too tired to proceed farther. Being neither the one nor the other, after dining on chicken, bread and tea, and resting an hour on a wide shelf covered with mats, we pushed on seventeen miles farther, passing many herds of wild cattle, reaching the Volcano House at sunset.

Tired as we were, we looked upon this grass house as a delightful haven of rest. It has now been replaced by a modern, more sumptuous, and far less romantic hotel, of which I have nothing to say. The girls, whom we called the "Lambs," cramped from the unaccustomed exercise, had to be taken from their horses. This grass house, owned by a native and kept by a Chinaman, was very cosy. One does not know until he travels in these out-of-the-way places, how little it takes to make one comfortable, and how much of what is considered indispensable for civilized life is really unnecessary luxury. One of the great lessons taught by travelling is to be content and even happy with a little: grumbling not only sours one's own temper, but irritates those who are not to blame for not supplying impossibilities.

The last half of the ride was hard from its steepness, mud and clinkers, but all fatigue was for the time forgotten as we neared the crater, and came in sight of the ever-rising fumes of the volcano. All around the ground was smoking and steaming with sulphurous and watery vapors, giving unmistakable indications

of the fire raging beneath us. The sunset was very grand over Mauna Loa, for the depth and variety of the colors, the huge slumbering mountain above us, and the deep lava pit below. The house was on the very edge of the crater, and from its porch you looked directly into it. The fires after dark, at the distance of about three miles, resembled the flames issuing from the chimneys of immense furnaces. The night was very dark, the fires glowing, ever changing, but noiseless, the stillness broken only by an occasional crackling, and the hissing of the steam from crevices near the house.

The hotel, one of the half-dozen known only to the entire island group at that time (1872), was made of thatch. It was impervious to wind and rain, was comfortably furnished, and well supplied with eatables and drinkables at fair prices, considering the difficulty of their transport. The only article which was not good was the water; this was scanty and reddish, with a decided flavor of musty straw, most of it being caught in an old canoe set under the eaves to receive the drippings from the thatched roof: I think our tired animals did not get any.

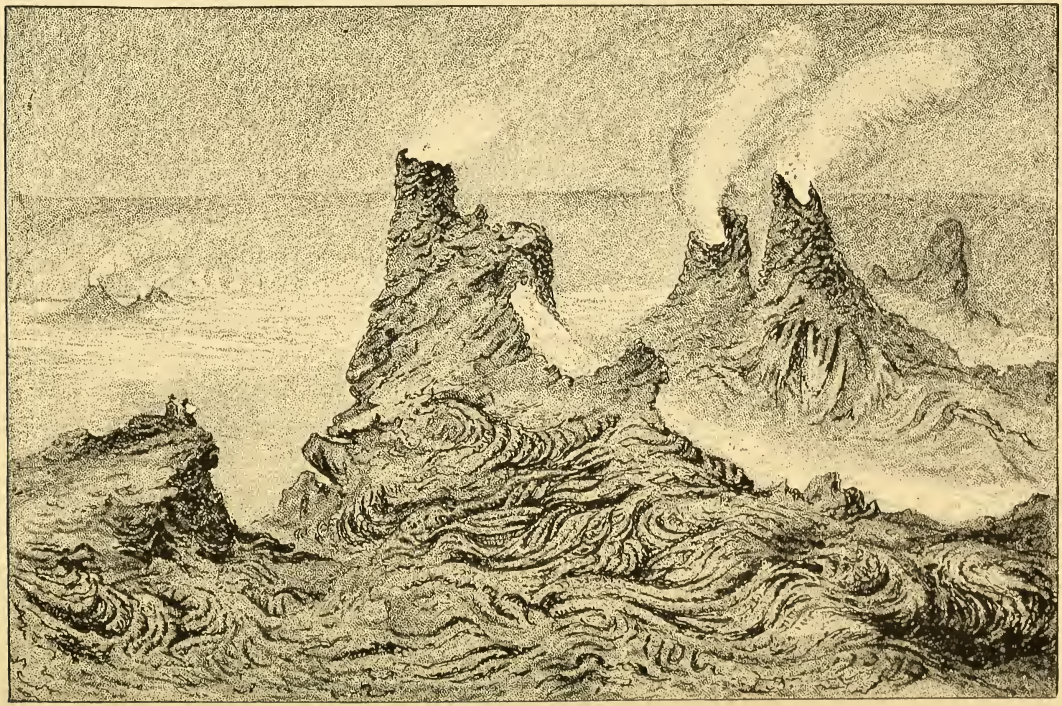
There was a rousing fire in the open fireplace, for the night was cold, as we were over four thousand feet above the sea. The parlor was fitted up with flowers, evergreens, pictures, books, and everything to make it pleasant: a few large roaches and spiders — natural enemies — and small scorpions, enjoyed the comforts with us. They did not offer to come near our persons, though one naturally looks with aversion and suspicion on such companions. The neat fence was bordered with wild roses in bloom, and it was altogether a charming spot.

Near by on one side was an immense bank of sulphur, from which the fumes were constantly escaping, with hot sulphurous

vapor which one of our party utilized as a bath, in a hut made for the purpose. He was nearly baked alive, as he was imprisoned in a box, with only his head out. The native attendant, not understanding English, even of his emphatic kind, mistook his cries for a demand for more heat, which he very soon got; at last he succeeded in getting out by a vigorous use of his lungs and his fiercest expression of countenance. He had been sitting over a hole evidently communicating with the fires below, and was of the firm opinion that it was a mistake made on purpose. On the other side of our house was a deep pit from which a hot damp breath was constantly escaping, and all about us the ground was steaming, indicating that the whole locality was underlaid by fire.

After breakfast, next morning, taking lunch and water with us, we started for the descent of the crater. Though the sun was hot, a strong breeze enabled us to make, without great fatigue, what otherwise would have been, and generally is, a hard tramp. We felt rather stiff at first, having to descend by long steps an almost perpendicular wall of lava, two hundred feet high, overgrown with shrubbery, and evidently very old.

Reaching the lava proper, we descended by a gentle slope some hundred feet more, to the bottom of the crater. This a few years ago was a boiling cauldron; and even now through the cracks the heat and sulphur incrustations made it evident that we were walking on a shell that might at any moment be broken up and precipitate us into a lake of molten lava. The lava was sometimes ragged and cracked, at others twisted into all imaginable shapes. The best thing I could compare it to was a great mass of black molasses candy, which flowed slowly, hardened, and remained in whatever form the cooling process left it.



KILAUEA IN ERUPTION.

This crater, on the floor of which we stood, was then solid at the surface, except at the extreme southern end. It is nine miles in circumference; nine times as large as Boston Common; and during the first third of this century was a great sea of boiling lava. The walls are from six hundred to nine hundred feet high at most places, and everything, everywhere, is lava. The crater is a depression in the side of Mauna Loa, about four thousand feet above the sea; the distance from it to the summit of the volcano is twenty miles. The mountain, which rises to the height of fourteen thousand feet, and the diameter of whose base is at least sixty miles, is not steep, and the ascent is so gradual that you would hardly think you were ascending very much till you get near the top. The amount of material thrown out is almost beyond belief; the islands, in fact, — and Hawaii is about as large as Connecticut, — are composed, at any rate above the water, wholly of lava.

The walking was generally easy, as the floor was smooth, and covered with a thin glassy crust, breaking under foot with the feeling and sound of thin ice, preventing slipping, but very destructive to shoes. The smoking part of the crater was some three miles off, and we arrived in its neighborhood toward noon.

Before getting to the real crater, we had to pass close to two small cones. These threw out choking sulphurous fumes, and the heat in the air and under foot was all that we cared to endure. There was no noise, but simply a small jet of gases and vapors from a cracked cone about fifteen feet high, which, as we quickly passed, we could see was red-hot on the inside. After hurrying through this hot smoke, we reached the "Lake of Fire" (Hale-mau-mau, the "Everlasting House"), at that time the only active portion of the volcano. The sharp and brittle fragments

over which we scrambled were only two weeks old, and climbing up the steep ridge of hot and crumbling ashes, we instinctively held on to each other, and looked down. It was the most awful sight I ever beheld.

Imagine an irregularly circular cauldron, with an estimated depth of two hundred feet and one thousand feet across (estimated only). At the bottom of this a waving mass of fluid lava, rolled and swelled like the undulations of a sea of melted lead, for the most part covered with a sulphur-colored scum. This was gently heaving and falling; on the sides, at the base, were large caverns, into which the lava dashed like thickened waves, the cavern sides and the surges red-hot. In the middle of this lake was a large mass of boiling blood-red liquid, from the centre of which, from time to time, were thrown up jets of dull red lava about forty feet high and three feet in diameter, falling back with a heavy fearful "thud," indicative of its weight and density.

It was a magnificent sight, and well repaid us for a voyage of six thousand miles to see. The heat, the sulphur fumes, the dull roarings, the quivering ridges, the horrid color of this "lake of fire," had a strange fascination, luring one to leap into its unearthly and beautiful embrace. Within six feet of us was a red-hot cone, covered outside with incrustations of sulphur, roaring in our very faces, and revealing to us the hollow, fragile, and treacherous character of the rim on which we had prostrated ourselves. The fascination took away all sense of fear and of danger; a feeling I had once before experienced on the bloody battlefield of Newbern, N. C., in 1862; the terrible scenes of the battlefield and the awful splendor of the fiery lake awoke in me the same sensation of self-forgetfulness and afterward of horror. Remaining some fifteen minutes,

until a sudden change in the wind drove the sulphurous fumes toward us, we were reluctantly compelled to retreat. We did not realize, until we were at a safe distance, to what a terrible death the falling in of this portion of the edge would have consigned us. The walls are constantly changing from this cause. We had, in fact, though feeling secure in the presence of our guide, been stationed on a thin, fragile crust, over a red-hot lava-filled cavern. So well do the guides know the symptoms of danger, that I think no accident has ever happened at this crater.

The state of things we witnessed they call "not active." You may imagine, perhaps, the infernal scene when this pot overflows its rim. This it did two weeks before and two weeks after our visit. We had walked over a lava crust which had hardly become solid, and was not cool. When the whole bottom of the great crater is sending up its glowing jets, as it has done within fifty years, and is covered with a sea of liquid fire, the sight must be terribly grand.

After partaking of a frugal lunch, with most welcome water, — for our thirst from the heat and the sulphur was great, — we walked leisurely back. When we reached the grass-covered lava, near the foot of the upper terrace, — for the ascent was difficult, — we found many so-called huckleberries (*ohelos*), looking more like cranberries; juicy, but insipid, though excellent quenchers of thirst. We were not so tired the next day but that we took a horseback ride of seventeen miles, and one of twenty the day after, to reach the southern part of the island on our way to Maui; the greater part of these journeys being over very rough roads and through a most desolate region, often visited by sudden drenching showers, against which a

pretty good protection was afforded by our waterproofs strapped, when not required, conveniently behind our saddles.

This largest active crater in the world, by the side of which Vesuvius is utterly insignificant, affords to the lover of the grand in nature an easily accessible, always active display of volcanic phenomena. It varies very much in intensity, but is ever more or less active, and appears to be independent of the eruptions of Mauna Loa, in whose side it is merely a small depression. About sixty years ago it was, in its whole extent, a raging sea of fire. In 1840 it was filled for five hundred to six hundred feet with molten lava, the immense weight of which broke through a subterranean passage of twenty-seven miles, and reached the sea, forty miles distant, in two days. It flowed for three weeks. The stream, where it fell into the sea, was half a mile wide, heating the water twenty miles from land, and, of course, killing multitudes of fishes. An eye-witness of this mighty flow of 1840 says: —

"When the torrent of fire precipitated itself into the ocean, the scene assumed a character of terrific and indescribable grandeur. The magnificence of destruction was never more perceptibly displayed than when these antagonistic elements met in deadly strife. The mightiest of earth's magazines of fire poured forth its burning billows to meet the mightiest of oceans. For two score miles it came rolling, tumbling, swelling forward, an awful agent of death. Rocks melted like wax in its path; forests crackled and blazed before its fervent heat; the works of man were to it but as a scroll in the flames. Imagine Niagara's stream, above the brink of the Falls, with its dashing, whirling, madly-raging waters hurrying on to their plunge, instantaneously converted into fire; a gory-hued river of

fused minerals; volumes of hissing steam arising; smoke curling upward from ten thousand vents, which give utterance to as many deep-toned mutterings, and sullen, confined clamorings; gases detonating and shrieking as they burst from their hot prison-house; the heavens lurid with flame; the atmosphere dark and oppressive; the horizon murky with vapors, and gleaming with the reflected contest. . . . Such was the scene as the fiery cataract, leaping a precipice of fifty feet, poured its flood upon the ocean. The old line of coast, a mass of compact indurated lava, whitened, cracked and fell. The waters recoiled, and sent forth a tempest of spray; they foamed and dashed around and over the melted rock, they boiled with the heat, and the roar of the conflicting agencies grew fiercer and louder. The reports of the exploding gases were distinctly heard twenty-five miles distant, and were likened to a whole broadside of heavy artillery. Streaks of the intensest light glanced like lightning in all directions; the outskirts of the burning lava as it fell, cooled by the shock, were shivered into millions of fragments, and scattered by the strong wind in sparkling showers far into the country. For three successive weeks the volcano disgorged an uninterrupted burning tide, with scarcely any diminution, into the ocean. On either side, for twenty miles, the sea became heated, and with such rapidity that on the second day of the junction of the lava with the ocean, fishes came ashore dead in great numbers, at a point fifteen miles distant. Six weeks later, at the base of the hills, the water continued scalding hot, and sent forth steam at every wash of the waves."

This crater was thought to be the favorite residence of the heathen goddess Pelé, and the various eruptions were believed

to be the demonstrations of her anger. There are many curious and interesting traditions connected with Kilauea, which will be found in the volumes of Jarvis, Ellis, and other writers on the Sandwich Islands. "Pelé's hair" is the name given to glassy threads of lava which, spun out by the wind and the fiery blasts, cover every object near the crater. This "hair" is so light as to be carried by the wind to Hilo, thirty miles distant. I saw there a bird's nest, containing eggs, which had been constructed of this glassy, thread-like lava. Such a one, possibly the same, was exhibited from these islands at the Philadelphia Centennial Exposition in 1876.

Kapiolani, a high and rich princess of Hawaii, gave the death-blow to the Pelé superstition by going, in 1825, to the crater of Kilauea, with numerous attendants, and, as a Christian convert, defying in public the power and wrath of the goddess. This journey of one hundred miles she made on foot, horses being then unknown on these islands. The native mind was thoroughly convinced by her sincerity and boldness, and by the absence of the expected deadly results.

Though the royal family embraced Christianity many years ago, their faith was not of a character which profoundly influenced their lives. When Kamehameha the Fifth died in 1872, it was stated that he was not wholly free from the superstitions of his ancestors. It was common talk in Honolulu that he often consulted and implicitly obeyed an old sorceress of his household, and, though professing to be a Christian, held communion with the shark-god and other heathen divinities. If the Honolulu papers are to be believed, after his death and before burial, many of the old horrible and disgusting heathen practices were revived within the inclosure of the palace grounds.

In March, 1887, news was received from Honolulu that the Princess Like Like, the youngest sister of the king, had voluntarily starved herself to death to appease the anger of the goddess Pelé, which was supposed to be manifested by the great eruption of Mauna Loa, and which required as atonement a victim of the royal blood. It is most likely that the sorcerers effected this sacrifice of the accomplished princess by craft and cruelty. By a singular coincidence, when her death was announced, the eruption ceased, thus confirming the people in their old belief, much to the advantage of the sorcerers.

CHAPTER III.

THE HAWAIIAN ISLANDS. — MAUNA LOA.

Kapapala. — Earthquake and mud eruption of 1868. — Waiohinu. — Insect pests. — Eruptions of Mauna Loa. — Eruption of 1872. — Activity of Kilauea at same time. — Camp on the mountain. — Description of the lava fountain and flow. — Ice at the summit. — Changes in the floor. — Great flow of 1852.

AFTER leaving Kilauea, we took a trip over the old fields of lava, eruptions of various ages, to the sea, on the southern part of the island, in the district of Ka-u, a distance of about forty miles. Our first point to visit was the cattle ranch of Mr. Richardson, an American, whose hospitality was as unbounded as his words were few.

The first eight miles were so rough, and the clinkers so hard and irregular, that the horses could not go faster than a walk. Everything around was lava; some new and rough, others smoother and covered with vegetation more or less dense, according to its age and consequent decomposition; but generally the country was of extreme blackness, desolate, and waterless. Kapapala, in the great eruption of 1868, was so thoroughly shaken by the accompanying earthquakes that every stone wall was leveled, the cisterns cracked, the house moved from its foundations, and everything in it in the shape of crockery broken, except a pitcher and a cup, which the proprietor proudly shows as proof, to use his own expression, that "times were pretty lively then."

At almost any time during an eruption in the stillness of the night may be heard the grumblings and felt the quiverings from the fiery cauldron which, no doubt, is always boiling under the volcano on whose sides we are travelling. On the night of our visit a small earthquake gave the house a thump, but it was all over before we could get to the door, toward which we all naturally hastened. It seemed as if some Titan had thrown a huge rock at the bottom of the house, and had not missed his aim. The sensation must be experienced to be understood; it cannot be described. The city of Charleston, S. C., in December, 1886, had ample opportunity to study earthquake shocks.

Next day we rode by the famous mud eruption near Kapapala, one of the disasters of the eruption of 1868. It occurred in a charming valley, verdant with groves of trees and rich grass, where thousands of cattle and goats were grazing, and where were several huts occupied by the native herdsmen. During the earthquake alluded to, there burst out, from a rent in the side of this valley, with a great noise, a stream of red mud and water, with many large stones. These materials were driven, by the explosion, fully three miles. So great was its force that none fell on the ground within a distance of one third of a mile; it extended, three miles from the opening, from half a mile to a mile wide, and in the middle thirty feet deep. It covered an area of at least one thousand acres, and must have weighed several millions of tons. It buried everything in its course, destroying thirty-one human beings, and about one thousand head of cattle, horses, sheep, and goats. Mr. Richardson estimated his loss at fifteen thousand dollars. When we saw the valley it was overgrown with vegetation, and presented few traces of the terrible convulsion which must have devastated it.

Before reaching the sea at Kaalualu, we had to ride nearly thirty miles more, over similar detestable lava roads. We were scorched by the sun, parched with thirst, and occasionally soaked with rain. The only oasis in this black desert was Waiohinu ("sparkling water"), nine miles from the sea, through whose beautiful valley runs a never-failing stream of pure water. The delights of this place, however, were sadly interfered with by myriads of mosquitoes, immense flying roaches, and very large spiders, which freely enter the houses. The spiders prey upon the roaches, and neither insect attacks your person; but it was not pleasant to see them crawling in every direction over the floor on which we slept, or lurking in every corner.

At Kaalualu, during the eruption of 1868, a tidal wave forty to fifty feet high swept up the shore, washing away store-houses and dwellings, and killing many people.

From the summit of Haleakala, on Maui, we saw a bright light, which we took to be an extraordinary eruption in Kilauea. It proved to be, however, a grand volcanic display from the summit crater of Mauna Loa, which two of our party returned to witness.

This eruption, or rather the ejection of lava, from the summit crater of Mauna Loa, in August, 1872, was the first one ever witnessed in burning activity by the eyes of white men; and one of our party was the first to attain the summit, and the first to see and describe this magnificent scene. The description, which was published in the Hawaiian papers, and in Silliman's Journal, was the result of the visit of a second party, some days after ours, and when the fires had lost much of their first activity.

Eruptions or ejections at the summit have been very rare, and, till 1872, have never been studied on the spot. In 1832,

there was an eruption both from the summit and from Kilauea; but the former was not visited when active. In 1843, in January, a flow took place on the northeastern slope about thirteen thousand feet up, but not from and in the summit crater, which is one thousand feet higher. This flow continued about three months; was nearly thirty miles long, and many miles wide, so that the amount of material ejected must have been immense.

In 1851 there was an eruption one thousand feet below the summit on the western side, which in four days poured out a stream of lava ten miles long, but less than a mile wide. In 1852 an eruption occurred some four thousand feet below the summit, extending twenty miles, half-way to the sea, on the eastern side, continuing for a month; it also flowed for twenty-four hours on the northern side, apparently from the summit.

In 1855 an eruption commenced in the summit crater, but the fire had ceased, and only ashes and gases could be seen when Mr. Coan visited it at the end of four weeks; but in the meantime a lateral crater opened, two thousand feet below the summit, on the northeastern slope, August 11. It flowed for thirteen months, the principal stream (and there were many lateral smaller ones) with its windings having flowed seventy miles, with an average width of three miles, and a depth from three feet on the edges, to three hundred feet in the middle. It flowed for about fifty miles under its own refrigerated cover; it came within a few miles of Hilo, and the general expectation was that the town would be destroyed.

In 1859, January 23, a flow broke out four thousand feet from the summit, and flowed sixty miles to the sea, on the northern side, in eight days, or over seven miles a day. It flowed for

some weeks, with great velocity, taking, in its course, the shape of cataracts, and of the ground over which it flowed, making ascents of five and even twenty degrees.

In 1865 there was a four-months flow in the summit crater; there was no overflow, and, as it occurred in winter, no one went up. In 1868 the flow began in the summit crater, but soon died out there, and was not seen again till it burst out in several craters low down the mountain. This was preceded by the severe earthquakes, and the mud eruption, alluded to above. The flow went to the south, overwhelming many houses in its course; it followed a valley about five hundred yards wide and ten miles long, extending to the sea, where it widened to two or three miles. The lava was of the smooth variety, and ten to twenty feet deep: other streams burst out at different elevations, one of them springing from a crater about a mile long, from which spouted columns of liquid lava, of a blood-red color, while stones weighing several tons were thrown to a height of five to six hundred feet. Sometimes these jets would be distinct, at others continuous for a mile in length. The grandeur of this ever-varying picture, with the great roar of these fiery fountains, must be left to the imagination, for it cannot be described. Below the fountains it was actually a river of fire, surging like a cataract, from two hundred to eight hundred feet wide, and twenty feet deep, rushing with a speed of ten to twenty-five miles an hour; according to the declivity over which it flowed. At night the scene was terribly intensified, and with the flashes of lightning and sharp thunder, it might well represent what occurred on a still grander scale in the azoic geological times, before our planet was sufficiently cooled to allow the existence of anything possessing life.

The eruption lasted only five days; but so dense was the smoke attending it that the noon-day sun appeared like a lurid ball of fire. The whole island was shrouded in darkness, and, wherever they spread, the sulphur fumes destroyed the vegetation. About four thousand acres of good pasture land were overflowed, and an immense district of worthless land was covered with a crust of ragged lava.

At about this time severe earthquakes, hurricanes and eruptions occurred in South America, and the East and West Indies. This leads to the inference that the causes are of a general rather than of a local character. The cause of this will be considered hereafter.

The eruption of 1872 began on August 9, and lasted over a month. The following condensation of the notes of one of our party, given here for the first time in a printed form, detail the same.

On their way the travellers naturally stopped at Kilauea, and descended the crater, going to Hale-mau-mau, or the South Lake. This, at our first visit, was at least one hundred to one hundred and fifty feet deep, but it had now filled up to within six feet of the rim, and to rush up and take a hasty view was all that the heat and suffocating gases would permit: the lava under its heavy surgings was liable to splash over or overflow at any moment.

They had scarcely left the edge when a small cone near the opening, about one hundred and fifty feet from their position, began to pour forth its lava, which came down the hill with a rush, dividing into two streams, one of which came directly toward them. They left in a hurry, and stood not on the order of their going, having to cross, in their retreat, a stream of the

day before, just hard enough to bear their weight, the red-hot lava being distinctly visible through the numerous cracks. The heat was almost unendurable, both in the air and under foot. Having reached an old and now solid flow, they watched the stream, and saw the rapidity with which the surface cooled, the action underneath frequently breaking it up into large pieces, turning about like cakes of ice on a river, over which the cherry-colored molten lava oozed up and over. This was quite an exceptional sight for the crater of Kilauea, and during the night, which was cloudy and very dark, the many little fires looked like twinkling stars, so that it was easy to indulge the illusion that the beholder was gazing downward upon the heavens from some distant higher space.

From Kilauea they proceeded to Richardson's ranche once again for the night; next morning to Ellis's ranche, in two hours; in one and one half hours more they reached the goat region, and an hour later had ascended to the cloud region, over meadows thickly covered with large, but tasteless, strawberries. In another hour their camping-ground was reached in a scattered grove of small trees, about seven thousand feet above the sea; here the tent was pitched for the night.

On one side streamed the light from Kilauea, and on the summit of the mountain to the northwest, the light from the great crater of Mauna Loa rose in a beautiful column to the zenith, so glowing and steady that it is not wonderful that, seen from Hilo or the sea, it looked like a column of fire instead of light. The night was uncomfortably passed, as the fleas were legion, and very active, and the water supply ran short. Next morning, after an hour's ride, the travellers had passed the limits

of vegetation, and nothing was to be seen in any direction but vast fields of naked lava. The toilsome ascent was broken by no sound but the crunching of the brittle crust of the lava under the feet of the mules. At a little after noon the summit was reached, where nothing met the eye but a boundless ocean of lava, except where, to the northeast, rose still above them the serrated crest of Mauna Kea.

Between the point where the first view of the eruption was obtained and the crater itself, was a high precipice about a mile long, above the top of which could be seen a fountain of lava playing with great regularity, but of so small a size as to be inadequate to produce the wondrous light which had for so long a time illuminated land and sea.

Half a mile further to the east, the scene burst upon the vision in all its splendor. From the centre of a small cone, with an apparent diameter of two hundred feet, sprang a jet of molten lava not less than three hundred feet high, and about one hundred feet in diameter. There was an opening on the northeast side of the cone, from which flowed a river of lava, which gradually widened into a broad lake, and from the other end of the lake took its course along the base of the precipice which separates the north from the south side of the crater. It is useless to try to describe such a terribly beautiful spectacle. The fiery fountain was the principal feature; it had a strange fascination about it, and a "music in its roar" not unlike that of Niagara, but without the concussion and irregular booming sound of the great cataract. Imagination can hardly conceive the energy of the internal forces which could keep this heavy molten column in perpetual suspension so many hundred feet high, and for several weeks.

The height of this point, as taken by an aneroid barometer, was found to be fourteen thousand feet.

There is now no trace of the village marked out by the Wilkes Exploring Expedition in 1841. At this elevation one of the native guides fell exhausted, and all, on the least exertion, suffered more or less from the rarity of the air. The night was very cold, and there was ice an inch or two thick over the pools of water which abounded in the crevices of the lava.

The mules, having nothing to eat at night, very wisely, but unfortunately, gnawed off their halters and made tracks for the valley. One faithful animal remained, as his halter was tougher or his appetite less sharp; upon him was piled a mountain of saddles and camp equipage, and the party followed him down over the rugged and trackless lava, reaching the lower camp in five and one half hours, with their sole-leather in a very dilapidated state, and their feet in scarcely good walking condition. Reaching the bottom they found another party, including a lady, about to make the ascent; and it is the record of this second party, who missed much of the original grandeur, that has appeared in various public prints.

The distance from Hilo to the summit is sixty-six miles, and only sixty-one from the southern part of the island; all of this must be done on horseback or on foot; fatiguing, indeed, but it has been accomplished by several ladies.

The summit crater, Mokuawéowéo (the "red crack"), is the most perfectly formed, though not the largest crater on the islands. It is a deep pit, with perpendicular walls, somewhat broken, seven hundred and eighty-four feet deep on the west, and four hundred and seventy feet on the east side. Captain Wilkes describes the floor as nearly level, when he made the

ascent in the winter of 1840, with a large party of natives, seamen and officers. The suffering from the cold, mountain sickness, and fatigue, was very great, and two men died therefrom. Most of the cones seen by him have disappeared, and about one third of the floor has subsided two to three hundred feet, and from this sunken portion the flow of 1872 occurred.

The diameter of the crater is eight thousand feet, or nearly one and one half miles, and is of an irregularly oval shape. The slope from Kilauea to the sea is only one and one half degrees, and the average slope, according to Dana, only six and one half degrees. This makes a flattened outline, quite different from the usually received notions of a volcano with steep sides.

The description in Silliman's Journal differs little from the one above given, though the grandeur had evidently somewhat lessened. The activity in the summit crater lasted for more than a year. In August, 1873, the glare lighted up the whole island, and was seen by vessels one hundred miles distant. At this time a party, including a lady, made the ascent, and witnessed, though in diminished grandeur, the scenes of 1872. Kilauea was also exceedingly active, and the South Lake had many times overflowed, the retreating lava building up partitions from its bottom enclosing walls seemingly independent of each other.

In November, 1880, a great eruption broke out in the evening, about six miles north of the summit crater, the lava flowing between Mauna Loa "lofty mountain" and Mauna Kea "white mountain," and dividing into two branches, one going toward Kilauea, and the other threatening Hilo. The stream was some forty miles in length, one to two hundred yards wide, and about twenty feet deep and flowed like a river of melted rock. It

moved slowly, but with irresistible force, bearing on its surface huge bowlders, of tons in weight. No fire could be seen except at its front edge, which appeared red-hot. The noises were not of explosions, but prolonged roarings like those of hundreds of furnaces in full blast. Of course the tremendous heat rendered a near approach impossible. It destroyed great forests of koa trees, but, fortunately, in the capricious way in which lava often moves — turned aside from Hilo.

News has lately been received of an eruption, accompanied by severe earthquakes, which began January 15, 1887. The lava flowed down the south slopes, and, after a course of twenty miles, reached the sea without doing great damage.

As I cannot find words to express the terrible splendor of a torrent of fiery lava, consuming everything organic in its way, I will, in order to give a faint idea of these scenes, quote a few passages from a letter of Rev. Mr. Coan to Silliman's Journal, in 1852, describing his visit to the great flow from Mauna Loa in that year.

Omitting the details of his difficult and dangerous journey from Hilo to the lava stream, it is enough to state that at half-past three on the afternoon of the fifth day, he reached the crater, and stood alone in the light of its fires. It will be remembered that this eruption broke out about four thousand feet from the summit, flowed twenty miles east toward the sea, and continued for a month.

Mr. Coan says: "It was a moment of unutterable interest. I seemed to be standing in the presence and before the throne of the eternal God; and, while all other voices were hushed, his alone spake. I was ten thousand feet above the sea, in a vast solitude, untrodden by the foot of man or beast; amidst a

silence unbroken by any living voice, and surrounded by scenes of terrific desolation. Here I stood, almost blinded by the insufferable brightness; almost deafened by the startling clangor; almost petrified with the awful scene. The heat was so intense that the crater could not be approached within forty or fifty yards on the windward side, and probably not within two miles on the leeward. . . . I approached as near as I could bear the heat, and stood amidst the ashes, cinders, scoriæ, slag, and pumice, which were scattered wide and wildly around. From the horrid throat of the cone (of eruption) vast and continuous jets of red-hot, and sometimes white-hot, lava, were being ejected with a noise that was almost deafening, and a force which threatened to rend the rocky ribs of the mountain, and to shiver its adamantine pillars. At times the sound seemed subterranean, deep, and infernal. First, a rumbling, a muttering, a hissing, or deep premonitory surging; then followed an awful explosion, like the roar of broadsides in a naval battle, or the quick discharge of park after park of artillery on the field of carnage. Sometimes the sound resembled that of ten thousand furnaces in full blast; again it was like the rattling of a regiment of musketry; sometimes it was like the roar of the ocean along a rock-bound shore; and sometimes like the booming of distant thunder. The detonations were heard along the shores of Hilo. The eruptions were not intermittent, but continuous. Volumes of the fusion were constantly ascending and descending like a *jet d'eau*. The force which expelled these igneous columns from the orifice, shivered them into millions of fragments of unequal size, some of which would be rising, some falling, some shooting off laterally, others describing graceful curves; some moving in tangents and some falling

back in vertical lines into the mouth of the crater. Every particle shone with the brilliancy of Sirius, and all kinds of geometrical figures were being formed and broken up. No tongue, no pen, no pencil, can portray the beauty, the grandeur, the terrible sublimity of the scene. . . . During the night the scene surpassed all power of description. Vast columns of lava at a white heat, shot up continuously in the ever-varying forms of pillars, pyramids, cones, towers, turrets, spires, minarets, etc. The descending showers poured in one incessant cataract of fire upon the rim of the crater down its burning throat, and over the surrounding area, each falling avalanche containing matter enough to sink the proudest ship. A large fissure opening through the lower rim of the crater gave vent to the molten flood which constantly poured out of the orifice, and rolled down the mountain in a deep, broad river, at the rate, probably, of ten miles an hour. This fiery stream we could trace all the way down the mountain, until it was hidden from the eye by its windings in the forest, a distance of some thirty miles. The stream shone with great brilliancy in the night, and a long, horizontal drapery of light hung over its whole course."

CHAPTER IV.

HAWAIIAN ISLANDS, HALEAKALA, THE MOON.

Island of Maui. — Kona, Hawaii. — Waihee — Wailuku valley. — Geese without webs. — Rain and drought. — Ride to the summit of Haleakala. — Hard climbing. — Labor school. — Size of crater. — Its walls and cinder cones.—Night upon the summit. — Magnificence of moon and clouds effects. — Volcanic scenery of the moon. — Huge crater of Copernicus. — Volcanoes without water.

THE island of Maui, the second largest of the group, lies to the northwest of Hawaii and within sight of the island. It contains the largest known crater, that of Haleakala, the "House of the Sun," now extinct, in height over ten thousand feet. Several small islands in the neighborhood are probably the broken or isolated fragments of a former large semicircular island. Maui is a double island; the Eeka, six thousand one hundred feet high, on the western island, being separated from Haleakala on the eastern by a low sandy plain, a few feet only above the sea; this plain is some nine miles wide, but so difficult to see that vessels have stranded upon its beach, thinking it a water channel.

We started from Kaalualu, the southern extremity of Hawaii, bound for Maalea Bay, on the isthmus between the islands. After a seventy-five-mile horseback ride the little steamer, even with its crowded cabin, close air, huge roaches, and other vermin, was a satisfactory change. Rounding Hawaii, the black lava is noticed — very extensive, and perfectly desolate for miles

along the shore, and even far into the interior, especially where the flow of 1868 reached the sea.

We touched at Kealakeakua Bay, on the west side of the island, where Captain Cook was killed in 1789. The lava cliffs here are in many places quite perpendicular, and one can readily see why the natives gave it this name, which signifies "Pathway of the Gods." We next touched at Kona, celebrated for the excellence of its coffee, rarely found abroad, and for the salubrity of its climate, probably the finest in the world. The thermometer ranges from sixty to eighty degrees Fahrenheit, the heat being tempered by the mountain breeze at night, and the ocean wind by day; a temperature perfectly delightful for almost any debilitated condition, and one which physicians frequently prescribe. A hotel recently opened there furnishes all necessary comforts to invalids. At Tawaihae, just before crossing the rough channel to Maui, may be obtained at one time a splendid view of the three great volcanoes of Hawaii; viz., Mauna Loa, Mauna Kea, and Hualalai (the last two extinct), and the great one on Maui to which we were bound.

Crossing the channel, which is always rough, we reached Maui at the plantation of Ulupalakua, one of the largest and most productive sugar plantations on the island, whose industry is chiefly devoted to the cultivation of the sugar-cane. A two hours' sail brought us to the isthmus, where we landed in a small bay, then quiet, but the next week so rough that no landing could be made. Riding in a carriage across to Waihee we were struck with the red color of the soil, which is well adapted for sugar-cane if well watered, but otherwise sterile; hedges of cactus rose to a height of ten to twelve feet, their flat, distorted leaves bristling with spines so thickly

that a cat could hardly penetrate an inclosure surrounded with them. Now and then a solitary cactus would be seen in the middle of a field as large as a good-sized apple-tree, but sprawling its uncouth branches without the least symmetry. The land was so hard, and the roots of the cane so tough, that the usual team for ploughing was six yokes of oxen. Immense fields of sugar-cane in various stages of growth covered the country with their rich green; at a little distance a cane-field, just coming up, looked very much like a corn-field.

Before ascending to the great crater let us take a glance up Wailuku valley; one of the most beautiful of the many volcanic gorges of this island. The sides are not less than a thousand feet high, cut by the most picturesque lateral gorges from the subsequent effect of water and the sun, clothed with green to the very summit; a small clear stream winds through the valley, which is in some parts well cultivated, adding to the charm of the scenery, and furnishing the water necessary for the cane-fields and the crushing mill. After leaving the carriage horses are taken for a few miles, and are then dismissed, as nobody but a skillful and merciless rider can gain the top with a horse. We accomplished it on foot, and took our lunch on a high plateau which afforded a fine view of the gorge and of the ocean beyond. Here we saw several wild geese: a small species peculiar to the islands; very handsome, and capable of domestication. Though these birds are web-footed and well adapted for swimming, they are never seen near the water, but are confined in their wild state exclusively to the mountain region. Their webbed feet therefore are clearly of no use to them; they are even an impediment; and, from a Darwinian point of view, we might expect, if time enough be given, to see a goose without webbed feet,

or, at any rate, with the webs very much reduced in size; before that time arrives, however, the bird in the struggle for existence will probably become extinct, and thus frustrate us in our attempts to provide this most desirable answer to the derivative problem.

The summits of these mountains are almost always on this the windward side of the island enveloped in clouds which yield the rain for the lower streams. It rarely rains in the valley proper; and on the other side of the island, where these clouds do not occur, the land is dry, barren and useless until public or private means convey thither water which in other parts runs wastefully into the ocean. Maui is an older island than Hawaii, and the soil, of long decomposing lava, is thick, and needs only water to render it fertile.

The next day we started to ascend Haleakala. Our party consisted of six: three gentlemen and three ladies. We had also a guide, and several natives and pack horses to carry our tent and cooking utensils, for we intended to camp out that night, or the next, on the summit. We started from West Maui, the mountain being on the eastern island. Crossing the low sandy plain above alluded to, we were almost choked with the clouds of red dust set in motion by our own wheels and the strong wind from the sea. After several hours of a fatiguing and dusty ride, we arrived at Makawao, a large and well-conducted sugar plantation on the lower flank of the mountain, where we were most hospitably received. Next morning we started, on horses and mules, for the summit. A four-mile ride brought us to the Haleakala Labor School for Boys, carried on with great success. The ideas of the dignity of labor and of education in the industrial arts, will, if anything

can, make this indolent, aimless, improvident people an independent nation, and neutralize the influence of the Chinese among them, who possess all the traits which the natives lack.

The distance to the summit was about five miles beyond this, and soon the climbing began in earnest; the last four miles of the trail very rough and hard, and we frequently dismounted and walked, to save the horses which panted heavily, the exertion in the rarified air being felt by them as well as by us to be unusually fatiguing. About a mile from the top we came to a large cave in the lava, often occupied by travellers as a shelter for the night; but we had a tent with us, and as our guide said that the fleas would sadly torment us there, we pushed on for the summit, which we reached at five P. M. We now saw the reason for our numerous retinue of attendants, whose business it was to carry wood to the top for our fire, cooking and warmth. The lassitude we all felt on the least exertion, and the difficulty of breathing at this height, ten thousand feet, came to a ridiculous climax on our arrival at the camping ground. None of us at first could do anything but gasp for breath; one lady fainted entirely away, and a second came very near it, but a judicious and timely inward application of an alcoholic stimulant soon revived us all. While the men were pitching the tent under a projecting shelf of lava, which formed a partial protection from the cold and strong wind, and were making a fire, we went to look into the crater before it grew dark.

This, so far as known, the largest extinct crater in the world, is at least twenty-seven miles in circumference. Its vastness, depth, stillness and desolation are perfectly appalling. The walls are in some places perpendicular, in others so sloping that man and horse can descend into and cross it. The pit varies

from fifteen hundred to two thousand feet in depth, and the bottom is irregular from the old lava flows which have proceeded from the numerous perfect cinder cones now standing there, looking as fresh as if the fires had gone out yesterday. Though the fires were dead, and have been since the memory of the natives, the sight was grander than the burning Kilauea and Mauna Loa.

The air was chilly, and the fire in addition to all our garments was necessary to keep us warm. We amused ourselves till dark by rolling masses of lava into the depths beneath. Some weighed several hundred pounds, and were traceable, after bounding from cliff to cliff, only by the little puffs of dust they raised in the fine particles below; we knew there was no danger of harming any human being or his property, and the few wild goats would easily get out of the way.

The numerous cones in the crater were very symmetrical, and seemed quite fresh and small, though many were over five hundred feet high, and very old. One can not at first comprehend the size of this crater, and, when comprehended, it is to most persons the most impressive sight in the islands; such a circuit of dark precipices can be paralleled only in the moon, where they are indeed surpassed. It is most likely that both Haleakala and Mokuaweoweo craters are the result of many ancient ones which have been opened into each other: this is probably true of other great craters.

It is possible to descend into the crater almost anywhere, but the ascent, except in a few places, is so difficult that only the wild goats, the only sign of animal life there, can effect it. It is evident that the lava broke through the walls to the north and east, in valleys from one to three miles wide, as deep as the

crater, and extending to the sea. There is a tradition among the natives that these great streams burst forth while the island was occupied by their ancestors many centuries ago. The lava looks perfectly fresh in many places, but there are nowhere on the island any signs of present volcanic activity, in the shape of warm springs, steam jets, or sulphur fumes; this has long been an extinct crater.

After supper we saw a magnificent sunset. Later still a quarter-moon hanging in a cloudless sky above, gave an unearthly look to the great crater. We were above the clouds, and their scenery was exceedingly beautiful and peculiar. We stood on the top of a mountain ten thousand feet high, with the sea all around us, and the high land of Maui near us, yet nothing could we see but a continuous bank of fleecy clouds piled up below. Of silvery whiteness at first this cloud effect looked like a vast sea of ice. It was indescribably splendid. Standing on the brink of this dark and silent crater it seemed as if the ocean rose to the horizon, which hung midway between the zenith and the base of the mountain, the sun apparently setting half-way down the sky. The brilliancy of the moon, from such an elevation, free from the mists and clouds of earth, is singularly great. You seem to be much nearer than ever before to her orb, and do not wonder that she should have been worshiped as well as the sun, as a deity. The brightness is something supernatural, and, with the darkness of the non-illuminated parts of the crater and the unearthly stillness, strikes one with awe. When the moon does not shine, the darkness is sudden and intense, as there is no twilight in these islands.

We slept under our tent, on the ground, blankets above and blankets below, with whatever we could find for a pillow. From

the slope of our rocky bed we were continually rolling down upon each other. We disposed ourselves for warmth as closely together as possible; when one wanted to turn over all, at a given signal, must also turn. We did not sleep much, the hardness of our bed, the cold (forty degrees Fahrenheit), and the incessant chattering of our men outside around the fire preventing repose. The sunrise was almost as fine as the sunset, though not appreciated by our sleepy eyes. After a frugal breakfast we started on our return. The descent occupied five and one half hours and was more difficult and tiresome than the ascent. We had noticed, the night on the mountain, a bright illumination in the direction of Kilauea, which we supposed to be an active eruption in that crater; it proved to be the summit eruption of Mauna Loa, the visit to which by some of our party has been previously described.

The singular resemblance of Haleakala and other volcanic phenomena of the earth to the scenery of the moon may be farther impressed on the mind by an abstract of what Proctor and other modern astronomers and scientists have written and spoken in late years concerning the earth's satellite and her history.

Prof. Proctor has noticed the striking resemblance between the configuration of the American Continent and that of the moon's surface as seen through the best modern telescopes. The broad plains extending from the Missouri to the Rocky Mountains much resemble the so-called "seas" of the moon, bordered by ranges of mountains, beyond which lie the great volcanic craters. These show, with their prevailing dark tints, a former condition on the moon like that now found on the earth, especially in America, and indicate that the moon, now dry, had

once its large seas; the slow process by which these seas were changed to land is now going on on an extended scale and very slowly on the earth. We may read a similar chapter of resemblances in the volcanoes.

As we look upon the full moon, it is hard to believe that her face, bright only by reflected light, has been torn and convulsed by volcanic forces on a scale more grand than any yet known to the earth. The lofty and ragged precipices of the moon, her deep chasms, immense craters, barren and lifeless deserts, and dreary waterless plains, can not be paralleled on the earth. The dark portions of the moon, which at the full are thought to resemble the human face, are in reality dark shadows cast by the ridges and craters of extinct volcanoes. Of these the largest is Copernicus, with a width of fifty-five miles, — five or six times as large as any on the earth, — while its height is about eleven thousand two hundred and fifty feet. Its vast plain is surrounded by a circular wall, with central cones and huge bowlders distributed over its surface. In its vicinity are other craters, ridges, and gulfs of immense proportions, heights and depths.

The greater size of the volcanoes of the moon, and of those on the earth in distant geological ages, may be partly explained by the appearances described by Mr. Mathieu Williams, in his work "The Fuel of the Sun," and which he regards as masses of fused metallic cinders cooling without the presence of water, an element that seems to be essential for the production of modern volcanoes. In watching the cooling of the melted mass as it flows from the puddling furnace (the so-called tap-cinder of a blast furnace), into the stout iron boxes, or bogies, usually of a circular form, we may notice, first, a thin solid crust forming on the red-hot surface, which quickly cools and blackens. If

this crust is pierced, the red-hot matter beneath is seen to be in active movement, and a portion exudes from the opening. If left undisturbed in the bogie, a kind of volcanic eruption occurs, usually near the centre of the crust, sending spurts of the fused material to a height four or five times the width of the bogie; then a regular crater is formed, and small streams, representing lava, pour from it, sometimes irregularly and violently from the bursting of bubbles of gas; these form a cone as wide as the bogie, and often as high as half its depth. This study will afford, on a small scale, a typical volcano in eruption, and under circumstances resembling those of a highly heated planet or satellite, in the absence of water, where the fused materials have been inclosed in a resisting and contracting crust.

Applying this comparison to the moon, it is more reasonable to suppose that its crater-covered surface was due rather to processes like those described by Mr. Williams, than to the slow and intermittent action which we now notice in the volcanic phenomena of the earth; in the former case water would have been unnecessary, and vaporous matter to any great extent would not have been ejected. However much, therefore, the moon's surface may at first sight resemble Haleakala or such other portions of the earth's exterior, now or formerly rent by volcanic action, the cause may have been different; in the moon, as in our own planet in its first cooling age, the eruptions were doubtless produced as in the cooling of the fused matters in the bogies, and without the presence of water. In our present and extinct volcanoes, the centre being comparatively solid, the heat is probably due to the tension, fracture, and movements of the shrinking crust, the agency of water being a power-

ful, if not necessary, auxiliary in the production of the phenomena.

The mystery of the cold, silent moon, rent by deep chasms, covered by immense extinct craters, airless, waterless, lifeless, barren — an extinguished planet accompanying our earth — may reveal to the eye of prophetic science the doom of our globe and the whole solar system.

CHAPTER V.

ICELAND. — VOLCANOES AND GEYSERS.

Extinct craters and old lava streams. — Thingvalla and its chasms. — Volcanic upheaval on a large scale. — Long line of submarine fissure. — Skaptar jokul. — Hekla. — Its historic eruptions. — Scenery of desolation. — The geysers. — Great Geyser. — The Strokr, and what it did for us. — Explanation of geyser action.

IN the year 1874, during the Millennial Celebration in Iceland, I had the rare opportunity of visiting, under the most favorable circumstances, much of the characteristic volcanic scenery of that singular and far northern island. This was done during a journey to Thingvalla and the geysers. The trip was of necessity made on horseback, over a region for the most part barren, and hemmed in by volcanic ridges. In the distance some snow-capped mountains were seen, including the peak of Hekla. All the lava was very old, and covered with moss, while its angles were rounded by long exposure.

In this part of the island there is no tradition of any volcanic eruption since the advent of the Northmen. The ragged character of the surface, the marks of fusion, and the fantastic and twisted shapes, show, however, that this was the scene of great disturbance, and the sources of the molten material are evident in the surrounding heights. The lava does not differ from that noticed in the Hawaiian Islands and about Vesuvius.

On the way to Thingvalla the barren lava plain stretched as far as the eye could reach in almost every direction, while the

scenery became wilder and more desolate as we left the sea. The scene was gray and silent except for the hoarse croak of the raven or the shrill cry of the plover. The aspect was depressing, and seemed to carry the beholder back in geological time almost to primeval chaos. The approach is through the Almannagja, or the "Chasm of All Men," the exit being by a similar one, the "Chasm of the Raven," ten miles distant. The plain below, at the depth of one hundred and fifty to two hundred feet, was green and pleasant, with the river Oxer winding through it. Its whole expanse, some ten by five miles, was, no doubt, at a very remote period, a mass of lava on a level with the top of these chasms; the product of the Skaldbreid or "Broad Shield" volcano which is in full view to the north.

One theory of the way in which the valley was formed is, that this great plateau of lava sank either from contraction and depression at the time when solidification began, or from long subsequent falling in to fill up the abyss left by an earthquake or other volcanic disturbance. Another is that a more recent lava stream flowed over the old one, and that its weight, with its accompanying heat, broke in and fissured the cavernous layer beneath, from whose interior much of the old lava mass had drained away into the lake, leaving a comparatively thin crust above. Time and nature have, in a measure, covered its ugliness with a scanty vegetation.

The whole island has, in one part or another, been torn by volcanic agency, and most of the mountains seem to be in a state of intermittent activity liable to break out at any time. It was the chief volcanic centre in the basin of the Northern Ocean. Norway on the east and Greenland on the west show the primitive rocks of granite, gneiss, and mica slates, and these have

even been found in Iceland. Its nucleus was thrown up from a very deep ocean by volcanic power, but is nowhere more than half a mile high except where some of the volcanic peaks and plateaus attain a height of over six thousand feet. It consists chiefly of basaltic rock and silicious tufa, formed beneath the sea, the former raised in the tertiary, and the latter in the glacial period, the lavas having been subsequently poured out, entirely above water. The upheaving force appears to have followed a course from southwest to northeast. There must have been several extensive oscillations of the soil, and within the memory of persons now living, the coast on the north and west has risen considerably.

About one hundred miles north of the capital, and fifteen miles from the coast, is the Ellborg, which in the ninth and tenth centuries was an active volcano. This is a cinder or ash hill, about six hundred feet in diameter, crowned with a tower some two hundred feet high. Its lava ruins, of every shade of color, variety of form, and degree of roughness, resemble a vitrified sea.

The activity of the Iceland volcanoes, broken by various periods of repose, has been sufficiently described in books devoted to the island. Krabla, Katlugia, Hekla and Skaptar are familiar names in this connection. Their eruptions have been accompanied by terrible earthquakes, and the country has been devastated by water from the melted ice, mud, lava and ashes, with great destruction of life and property. Iceland is evidently on the line of a great volcanic fissure in the earth's crust, extending from Jan Meyen in the north, to St. Helena in the south; passing through the Azores, Canaries, and Cape de Verd Islands; a distance of one hundred and twenty degrees of latitude on very nearly the same meridian.

Since the year 1000 Hekla has erupted thirteen times, and Katlugia fifteen times. The few from Skaptar and Vatna jokuls have been of extraordinary violence, that of Vatna, in 1874–75, desolating some of the finest portions of the island. Krabla is surrounded by old craters or pits of boiling sulphurous mud. One described by Henderson was three hundred feet in circumference; horrible to look at, and dangerous to approach because of the fetid gases, treacherous soil and numerous pitfalls.

The most disastrous of all the eruptions on record was that from Skaptar, eighty miles east of Hekla, in June, 1783. It was preceded by violent earthquakes. The lava was in some places six hundred feet deep and two hundred feet wide, and flowed like a river towards the sea, one of the streams indeed reaching the ocean. It was in full activity for two and a half months; and continued, gradually diminishing, for six months more. The lava was more than two years in cooling. One stream was fifty miles long, twelve to fifteen wide on the plain, and one to six hundred feet deep. Another was forty miles long and seven wide; pasture-lands for one hundred miles around were covered by pumice, sand and ashes. The matter ejected was estimated at twice the volume of Hekla: one hundred thousand millions of cubic yards. This was, according to Bischoff, greater than the bulk of Mt. Blanc, and was probably as large as any single mass of the older igneous rocks known to exist.

Mt. Hekla presents a great variety of forms, according to the point of view of the observer, but the mountain always deserves the name of "cloaked," with its mantle of snow or canopy of clouds. The plain from which it rises is a very fertile one, and contains more farms than any other region of equal area. Its

barren and sandy portions, the work of the volcano, are strewn with rounded pebbles, worn by the constantly-shifting waters, the great rain-fall and the attrition of wind-blown sands.

The view of Hekla from our camp was exceedingly fine. The ascent of this volcano, though difficult, is not dangerous. It was ascended by Madame Pfeiffer in 1845, and has been achieved by several persons since. It is neither the highest nor the most remarkable of the Iceland volcanoes, but it has attracted the most attention from its comparative ease of access and its frequent and disastrous eruptions. Though only about five thousand feet high, with a circumference of twenty-five miles, it is one of the three great volcanoes of Europe, the other two being Etna and Vesuvius. It is isolated about thirty-five miles inland, and in clear weather can be seen from the ocean.

Hekla is composed of tufaceous slag, ashes and pumice, which are cemented by its own lava streams, and overlaid by silicious strata which are the result of submarine volcanic action. It is a part of a ridge of vast extent, belonging to the linear system of volcanoes, the crater changing along the extent of the fissure. It is surrounded by a circle of lower lava hills, by untrod glaciers and dazzling snow-fields. The ground about it seems undermined, and footsteps on the plain produce a hollow sound. The cone appears quite regular; the sides at an angle of about thirty-five degrees. It had, when we visited it, three peaks the central one being the largest. The craters are hollows in the sides, and, at the time of our visit, were completely covered with snow. It is rent with deep chasms, and numerous cones are scattered over the plain.

Since the first recorded eruption in the tenth century, there have been nearly thirty outbreaks. That of 1766 was very

violent, and continued three months, burying the fertile plain around it to an extent of ten miles. The eruption of 1845, also very violent, lasted seven months, and the ashes were carried by the wind to the Orkneys; more than six hundred miles away. A severe outburst occurred in 1878. All agree that there is no summit crater, the lava having flowed from great fissures on the sides, and presenting at the top an extensive and grand view of an immeasurable black chaos and shining fields of snow.

In 1875 one of the most extended and violent eruptions anywhere in modern times, occurred in the Vatna district, from a nest of volcanoes covering a region of snow and ice one hundred and fifteen miles long and sixty miles wide. It lasted several months, accompanied by such destruction of property, and even of life, that the whole country was impoverished, and Denmark and Great Britain were called upon to aid the starving people. The ashes from this eruption were carried in large quantities across the ocean to Norway. There is probably no part of the world, except the Hawaiian Islands and the Javan archipelago, that has been so frequently and terribly convulsed by earthquakes and overwhelmed by volcanic eruptions as Iceland; showing clearly that these are, independent of latitude, by the singular paradox of extensive glaciers, fiery lava streams and boiling geysers in close proximity.

Not less interesting are the geysers in the valley of Haukadal, a toilsome day's journey on horseback to the northward of Thingvalla. A ride of two hours along this sunken lava plain, which is in many places covered with vegetation, brought us to a black chasm extending from the lake to the mountains that form its eastern boundary. Difficult as was the descent by the western chasm, the ascent by this one was more rugged

because of the distorted character of the lava. Though only one hundred feet deep, the chasm is very much broken; the precipices overhanging and threatening to fall, the bottom filled with sharp, huge, irregular fragments, while below them lies a dark and treacherous-looking water. The grandeur and wildness are very imposing, and one feels like a pigmy visiting a battlefield of the Titans. This exit from this horrible pit would be impossible, and would necessitate a dangerous and fatiguing circuit of many miles, had not immense fragments happened to fall in such a way as to form a natural bridge across the chasm. It is a passage, however, which, during a high wind, or blinding storm, or from the slipping or fright of a horse, would be extremely perilous, and it is indeed always trying to ill-balanced nerves. The sun came out and warmed us, and the ponies carried us well over miles of desolation, as they could not easily leave the path without breaking their necks. Skirting one of the mountain meadows was a high volcanic ridge, one of whose old lava streams had suddenly cooled on the top, while the fluid contents ran out at the bottom. This had left a large cave which has long been used as a sheep pen; we did not enter, dreading the vermin which congregate in such places.

Passing around the flank of Hekla, with its mantle of glittering snow, we perceived far away in the distance what looked like a jet of steam, and imagined we were near the geysers. It was, however, only one of the many jets occurring in this region, telling of the subterranean fiery energies. At about seven P. M. — for it is light here till after nine — we came into the great verdant plain in which are situated the famous geysers. This excited us to hurry forward to witness the eruption

we fancied was imminent. It seemed like a paradise after so much barren lava, from the many flowers whose growth is favored by the heat and moisture.

In a space inclosing a quarter of a mile in length by three hundred feet in width are the Great and Little Geyser, the Strokr, and a dozen other smaller and nameless ones. The ground seemed honey-combed like a body pierced by foul ulcers, and from the pits and mounds were issuing steam, boiling water, and liquid mud, which made a sizzling and bubbling, and at times a thumping, that indicated an ample supply of heat and water that would soon cook us should the thin and resonant crust break beneath our weight.

Threading our way among these ugly-looking holes, we climbed a grassy hill above the Strokr, and pitched our tent. There was no time to collect wood and perform the ordinary cooking operations for a party of twelve famished persons, so our cook simply plunged some canned meats into the hot water of the Little Geyser, and in the same immersed our tea and coffee-pot. Very speedily our meal was ready without any expense of time or trouble in making a fire. The water at the surface was not boiling hot, and a finger could be rapidly passed through it without scalding the skin.

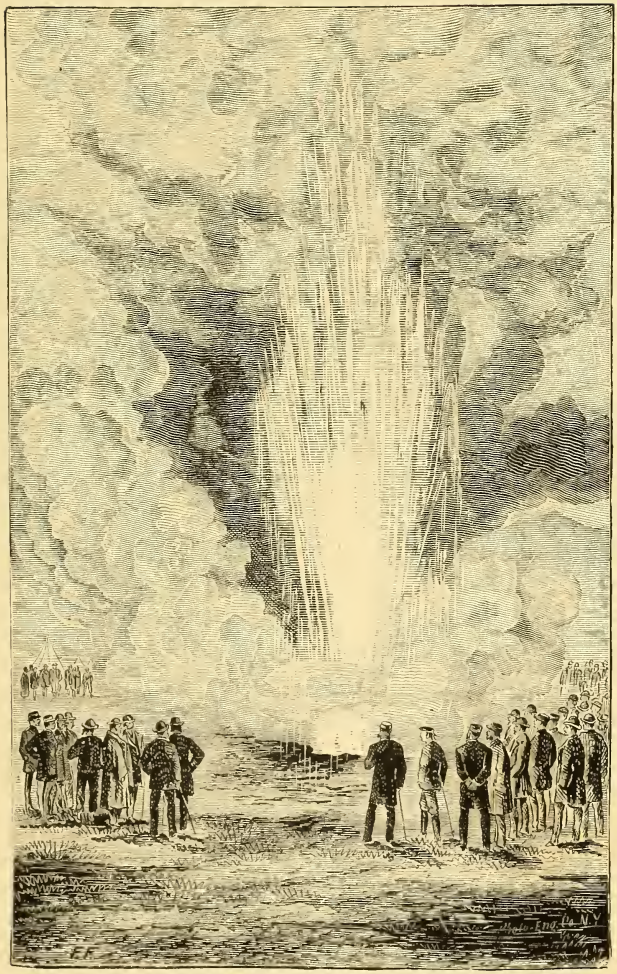
We went to sleep with one eye and one ear open, but their subterranean majesties, except by a few sullen thumps, as if to show their anger at the intrusion of the curious foreigners, made no exhibition of their powers. In this verdant plain, with the white icy mountains to the north, and the heat of the tropics under our feet, our surroundings seemed like a fairy scene rather than an earthly reality.

Geysers or spouting springs are found all over Iceland, some

sending up their steam jets from the midst of perpetual ice, and others bubbling up beneath the ocean near the coasts; but most are in districts in which the volcanic agencies are apparently dying out. Whether constant or intermittent, they nearly all deposit a silicious matter, forming the basin and the pipe, and finally closing the opening by their own incrustations. This shows the intimate relations of the geysers, both as to cause and source of supply, with volcanic lavas. Silic- and its compounds are the predominant constituents in both.

At a distance, the jets of steam so quiet and uniform, do not impress one with the real grandeur of the turmoil that is going on beneath the surface. They make less fuss than the California geysers and the Japanese hot springs. There are two kinds; one having jets of clear water, the other puffs of scalding vapor coming up through a soft, reddish, clayey mud impregnated with iron. Silica is held in solution by salts of soda, a silicate of soda being their principal ingredient. The water also contains sulphureted hydrogen, detected by the odor. Though most of this escapes as it cools, enough remains to injure the flavor of tea and toddy made with it.

The Great Geyser, which seems always to have been of about the same size, is situated on a mound of silicious tufa, of thin, easily detached plates, crumbling under the feet, deposited from the overflow of its own waters. The mound is twenty feet high and some two hundred feet in diameter, the basin resembling a saucer sixty feet across, and five feet deep. In the centre of this basin is a sort of pipe ten feet across, gradually narrowing to seven, and seventy feet deep where it ends or takes a turn which prevents further sounding; it is smoothly polished on the inside. Its eruptions are preceded and accompanied by



ERUPTION OF STROKR.

subterranean rumblings and boomings, causing the water and the soil to tremble. Its immense volume of water is thrown to a height of one hundred feet, ascending to its full elevation like a fountain, by spasmodic efforts, each more violent than the preceding, and assuming the form of a sheaf of silvery columns in an urn or tree-like shape. An eruption rarely lasts more than ten minutes, when the force is exhausted, and the water retires with a sullen roar within the tube, sometimes leaving the basin dry for several hours. When we saw it the basin was full, bubbling in the centre, and with an occasional elevation there and an overflow at the sides. The surface is usually covered with a dense steam. It is very capricious in its action. It would not spout for Prince Napoleon in 1856, nor for the King of Denmark and our American party in 1874.

The Strokr or Churn, is the most interesting of the geysers, as it may be provoked any day to show its powers by artificial means, viz: by pouring a cart-load of dirt down its throat. This was directly in front of our tent, and we went to work to get ready the pile of sods to produce the eruption on the morrow. Its mouth is a rounded hole in the rock about six feet in diameter. We could see the water, some twelve feet below, boiling with the usual bubbling and splashing of violent ebullition, and an occasional emission of steam. The whole depth is forty-four feet, and twenty-seven feet down the tube is said to contract to about eight inches.

Next morning the earth emetic was administered, and we retired to a respectful distance to await its operation. After waiting twenty minutes the internal commotion was much increased, with rumbling sounds; then the black mass was upheaved with violence in a column as large as the opening,

consisting of innumerable jets with whirling masses of sods. Some of the streams went rolling down the hill, but most fell into the mouth, to be again ejected. The eruption lasted about ten minutes in full force, and then gradually subsided, with a few high jets. As near as we could judge, the height attained was not over one hundred feet. Compared with that of the Great Geyser, the stream is slender and dark-colored. The eruptions will continue till the sods are discharged, or so broken up that they do not obstruct the escape of the steam. The sods were a stringy kind of peat, which retained their form and consistence for a considerable time.

Different theories have been advanced to account for these eruptions. The oldest one, and that favored by Prof. Lyell, is that water collects in subterranean chambers (which, from volcanic causes, must be numerous in Iceland); that this water, boiling from the elevated temperature of the strata existing between the crust and the nucleus of the globe, and whose movements from tension and fracture are converted into heat, is forced to the surface through natural openings by the compressed steam which ejects this water as a fountain or geyser. In the case of the Stroke the foreign matters introduced settle in the narrow throat of the pipe, and prevent the escape of the steam until the pressure becomes sufficient to throw out the obstruction with the imprisoned water.

Bunsen, Tyndall and others explain the formation, life, and extinction of a geyser, briefly as follows: —

By the action of carbonic acid, sulphureted hydrogen, and heat from the above mentioned cause, a hot spring takes its origin. It acts on the silicious strata about it, and separates the silica which it deposits on its overflowed margin; this incrusta-

tion, gradually increasing in height, is by degrees converted into a tube, which, in its ever-increasing mound of silicious tufa, becomes a geyser. The long, narrow tube is continually filled and replenished with a column of highly heated water, which, under the accumulated pressure of the mass above it, attains a much higher temperature than the original spring. The rapid generation of highly heated steam is the mechanical power of the geyser which, according to the heat accumulated and the resistance of the column, throws up the stream with violence, and maintains it till the equilibrium is restored.

When by deposits from its own waters the tube becomes so long that the supply of heat from below and the cooling at the surface of the column are so nearly equal that none of the water can attain the boiling point owing to an increased pressure, the eruptions cease, and the geyser becomes such a heated pool as is the so-called Little Geyser. It has been estimated, from the deposit of silica made in twenty-four hours, that the Great Geyser is about one thousand and sixty years old. In its earlier days it would be quite insignificant, and is not mentioned in the older Icelandic annals; it is probably now in its stage of decay. According to this theory the power of a geyser lies wholly in its tube, and is not due to steam accumulated in any imaginary and unnecessary subterranean cavern.

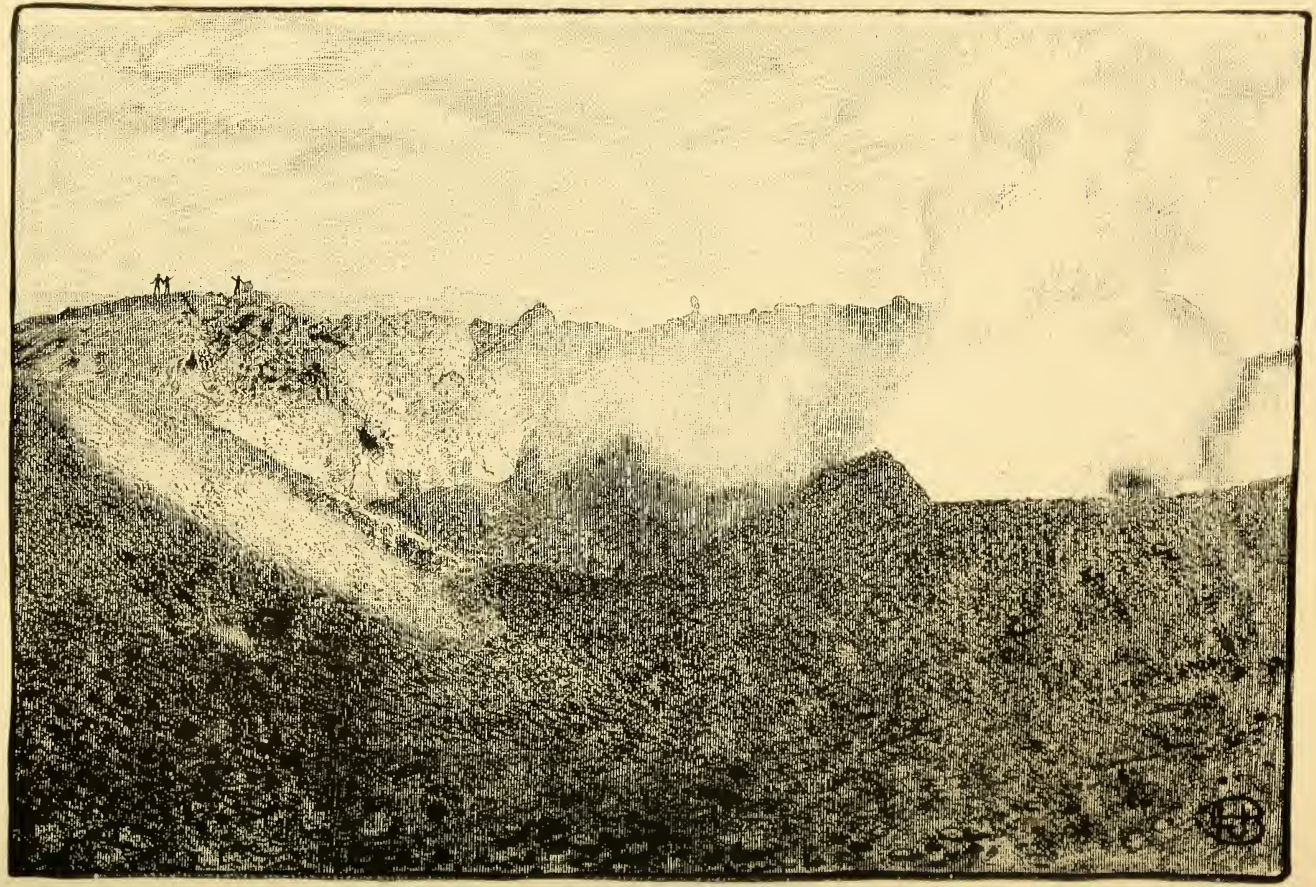
CHAPTER VI.

MEDITERRANEAN VOLCANOES. — VESUVIUS.

Gulf of Naples an immense crater. — Ancient and modern Vesuvius. — Recent eruptions. — Outbreak of 1872. — Ascent of the mountain by carriage and rail. — Observatory. — The crater by night. — On the brink. — Trembling of cone from swash of lava, and frequent volcanic bombs. — Difficulty of return from darkness. — Chemical composition of lavas.

VESUVIUS is about eight miles from Naples, whose bay it overlooks, at the eastern extremity of a chain extending to the island of Ischia, which was rent by an earthquake in March, 1881, and again in July, 1883. The whole Gulf of Naples, as above limited, was probably an immense crater; doubtless the eastern end of a great rent in the earth's crust, Etna being at the western extremity, and Stromboli in the centre. It seems not to have been the chief rent in historic times until A. D. 79, when Herculaneum [now Resina] and Pompeii were overwhelmed by its scoriæ and ashes, and the ancient crater of Monte Somma on the north and east was separated from the present cone by the valley of the Atrio del Cavallo, seven hundred feet wide.

The base of the mountain is over thirty miles in circumference; it is about two thousand three hundred feet to the base of the cone, which is in addition one thousand six hundred to one thousand nine hundred feet. The greatest recorded height of the summit, which varies after each eruption, is four thousand two hundred and fifty-three feet; the top is truncated some two



thousand feet in diameter, with a crater, on an average, five hundred feet deep. The observatory is two thousand and eighty feet above the sea; that on Etna is nine thousand eight hundred feet: one thousand five hundred feet higher than the Hospice of St. Bernard, and the highest inhabited spot in Europe.

The Vesuvius of the ancients was a truncated cone with a base of eight or nine miles, and a height of four thousand feet. At its summit was a depressed plain three miles in diameter. On this plain the gladiator Spartacus was besieged by the Romans, in the year 72 B. C. Vesuvius had never been deemed a volcano. Its sides were covered with fields and vines, and its crater overgrown with wild grapes. In A. D. 79 the great historic eruption formed the present crater and in this the modern cone has been built up. The mountain has undergone great changes during the last one hundred and fifty years; its bulk, as also its height, has increased, though varying from year to year by its own ejections.

Some of its lavas, being very liquid, have flowed rapidly, and almost like water, for miles beyond its base; others have been so viscid as to advance only an inch or two a day, for several years. When the lava is slow moving, as in 1858, it becomes wrinkled and folded; is coiled like ropes, or twisted like molasses candy, the chilled surface being crumpled by the heaving mass below; when rolling quickly, as in 1872, it is broken into enormous, rough, cindery ridges, with much emission of the imprisoned and active steam. As in Etna, great cones of trachytic acid materials have been inclosed by the later eruptions of less silicious basaltic lavas. Occasionally, as in 1660, ashes and smoke without lava have been ejected. The black dust is pyroxenic, while the white is leucitic, with chloride of sodium or salt, the insoluble parts being the same as in the lavas, and the

soluble as the gaseous matters which accompany the smoke; the last destroy vegetation by the free chlorohydric acid which they contain. The smoke strongly is positively electric; the falling ashes are negative. Flames are rarely seen, and, when present, are due to hydrogen and its combinations with sulphur; even these are faint, and tinged with various metallic oxides.

The frequent connection existing between earthquakes and volcanoes is shown by the history of Etna and Vesuvius. As in the former the earthquake of Melfi preceded the grand eruption of 1852, so in the latter that of Basilicato, December, 1857, ended with the eruption of 1858, while those of Calabria, in 1867 and 1870, were the precursors of the phenomena of 1868 and 1871–72.

It will be necessary here to simply enumerate the principal eruptions of Vesuvius since the memorable one which buried Herculaneum and Pompeii. Prof. Palmieri, of Naples, has laid it down as a rule that when, after a considerable period of repose, the central crater presents a series of small and frequent eruptions, a grand outburst may be expected. This was the case in 1822, and in 1855 (after thirty years of comparative quiet), and again in 1858, 1861, 1868 and 1872. The eruption of 1631, after centuries of inactivity, is really not an exception, as no one thought of danger from a mountain whose sides were covered with vegetation, and whose base was in contact with fertile plains. The antecedents were, therefore, not observed nor attended to. Automatic instruments now in use at the Observatory give and record the warnings of the slightest tremblings of the crater.

This eruption of 1631 came on suddenly and unexpectedly. It began on the sixteenth of December, and continued until

RAGGED LAVA. — VESUVIUS. — FLOW OF 1872. — ST. SEBASTIAN OVERWHELMED.

February, 1632. During this time the cone lost so much of its height as to be fifteen hundred and thirty feet lower than Somma. The flow nearly destroyed Torre dell' Annunziata, Torre del Greco, Resina, and Portici on the southwest slope, and torrents of boiling water from the melted snow, mud and lava, killed three thousand persons.

The eruption of 1779 was very grand. Stones were projected several thousand feet into the clouds of white vapor, with large masses of molten rock, and columns of fiery matters. In June, 1794, Torre del Greco was again destroyed by lava which flowed to the bay in a stream nearly a quarter of a mile wide and fifteen feet thick, estimated to contain forty-six million cubic feet. The eruption of October, 1822, continued for nearly a month, rupturing the top of the cone, and forming a crater three miles in circumference, and about one thousand feet deep. In May, 1855, the cone was again rent asunder. The flow continued twenty-seven days, and was very destructive to cultivated fields. In May, 1858, the Hermitage was nearly surrounded. In 1861 the eruption was very violent, but was of only seven hours' duration. It overwhelmed Torre del Greco, but on account of the intense cold the lava cooled very rapidly.

In the middle of November, 1867, a cone about seventy feet in diameter, which had formed within the large crater in two years, poured out a great amount of lava. Beside the main stream from the great crater, there was a flow from an outside orifice of twenty feet in diameter, and twenty-five feet wide, rapidly reaching the bottom of the mountain. With loud roars and heavy shocks, through the glowing vapor huge stones were sent many hundred feet high every few seconds. It continued until January, 1868, and is regarded as one of the grand eruptions.

The outbreak of April 24, 1872, had been preceded for several months by slight premonitory symptoms. Its greatest intensity was from the twenty-fourth to the twenty-sixth, after which it gradually diminished. The volcano had been quiet from November, 1868, to December, 1870, the previous eruption having ended in a copious stream from the rent cone formed on the first-named date. Early in 1871 the seismograph became inquiet, and, from the slight disturbance, Prof. Palmieri prophesied an outburst. Cones formed during the year, and in the early months of 1872. Crowds of people from Naples ascended the mountain nightly to witness the splendors. Several persons were buried in the Atrio del Cavallo by a flow of lava on April 26, from a rent in the cone one thousand feet wide on the northwest side. The Observatory was between two fiery torrents, and the heat was so intense as to break the window glass. Many small animals and countless insects perished, and the whole country was white from minute leucitic crystals resembling a saline efflorescene. On the twenty-seventh the flow had greatly lessened, but the matters ejected were estimated at twenty million tons. Much of this covered the lava of 1868, but the damage done to the fields and crops was estimated at three quarters of a million dollars. The bottom of the crater was broken up, and the sides were fissured in all directions. As Prof. Palmieri expressed it, "Vesuvius sweated fire."

Many of these rents are still visible. Pictures taken by the instantaneous photographic process show enormous volumes of globular vaporous masses, with numerous fragments thrown several thousand feet high; so many of these went as far as the Observatory, that it was unsafe to go out. Three principal fiery floods rushed down the mountain and far beyond its base,

overwhelming San Sebastian, Massa, and other hamlets, and many isolated houses. The streams gave off large clouds of steam, which formed miniature volcanoes in their course; the earth-tremors and vibrations were constant, with vivid lightning from the intense electrical excitement of the uprising column, and heavy rains from the condensation of the immense amounts of watery vapor. The streets of Naples were covered several inches deep with black sand, and the flow was at least three fifths of a mile wide at its lower portion. The people of the city and the neighboring villages fled to the country, with their movable valuables, as if fearing a catastrophe similar to the one so graphically described in Bulwer's "Last Days of Pompeii." From 1876 to 1886, there have been several insignificant eruptions, with very little escape of lava beyond the crater, an account of which may be found by those interested in the volumes of the "American Journal of Science and Art," for the respective years. A noted one occurred in 1880.

The ascent of Vesuvius has been robbed of most of its fatigue and excitement by the introduction of the steam railroad, which was commenced in 1875. It is customary now to take a carriage from Naples to the lower station, visiting on the way the dismal galleries of Herculaneum at Resina, rendered doubly gloomy by a cloudy day.

As we went up we passed over and along the lava streams of 1858 and 1868, of every degree of ruggedness and barrenness, and presenting the most fantastic forms. Mounting the steep zigzag, frequently in a gentle rain, with thunder clouds all about us, we could see the bay in a bright sunlight. We reached the Observatory in two and a half hours, where we stopped to examine the various instruments prepared for the observation of

earthquake and volcanic phenomena. Many of these are so delicate that the stamping of a foot would cause the registration of the vibration. This station was founded by Ferdinand the Second in 1841, under the direction of the distinguished physicist, Melloni; it is now presided over by Prof. Palmieri. It contains a fine collection of Vesuvian minerals, and memorials of the recent eruptions. Any disturbance at the summit is indicated by the automatic apparatus.

A half-hour's ride brought us to the lower railroad station. From here, by an endless wire-rope and steam windlass, we were drawn, in about fifteen minutes, near to the edge of the crater, by one section of one and one quarter miles, attaining the Atrio del Cavallo, and by the second, of two thirds of a mile, to the upper station, whence an average walker may reach the rim in fifteen or twenty minutes.

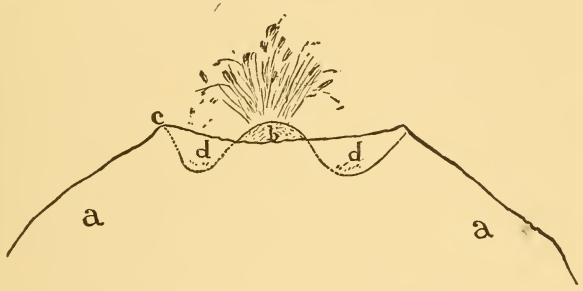
At 6.20 P. M. I started, with three ladies and four guides, up the gentle slope which winds around the summit to the grand crater. It was now quite cool, and the rarefied air made walking in the yielding sand and breathing somewhat tiresome and difficult. The rain had ceased, and it was growing dark in the plains below. When three quarters of the way up we met a strong puff of sulphurous vapor, which caused us to cough violently. Above us we saw driving clouds of what seemed this same vapor, and this so frightened the panting ladies that they dared go no farther. Leaving them in charge of three guides, to remain in a sheltered position till my return, I took the other and went on.

I found that most of the vapor was steam from the rain which had fallen on the hot rocks, though there were many streaks of suffocating gas which compelled me to breathe through all

ERUPTION OF VESUVIUS, 1880

the folds of my handkerchief. There was no path visible, so we scrambled as best as we could over rugged places, slippery surfaces and irregular fissures. The rocks were so hot that I could not bear my hand on them, while acrid invisible vapors issued all around from numerous small cones and ugly crevices.

It was now so dark that progress was slow, and the blinding vapor prevented my seeing before me or where to place my feet. Taking the guide's hand, I ran, slid, tumbled and crawled, with not a few wrenches and bruises, until at last I stood on the edge of the grand crater. The grandeur of the scene cannot be



A. Great crater.
B. Cone of eruption.
C. Where I stood.
D. Valley where stones fell.

described. I can simply say that in the midst of the great pit arose the cone of eruption, now and then hidden by vapors, and separated from my position only by a few hundred feet. Every minute or two there was a hollow, rumbling sound, and the whole summit trembled. This was caused evidently by the concussion or swash of the contained heavy fluid lava, which threw into the air and against its internal wall a great number of bright and dark fragments, describing curves of a hundred or two feet. Some fell back into the center of eruption, but the most of them into the valley between it and the outer rim, with a horrible stony clatter. This valley, which is two to three hun-

dred feet deep and wide, had its bottom and sides lined with fire; verily a bed of glowing coals. This rocket-like discharge occurred every two minutes, and hundreds of dazzling balls fell in every direction. During these terrible showers, several fragments, some a foot in diameter, passed over my head, but they were so large and few that it was easy to watch and dodge them. One struck near me, sending its glittering pieces all around. One, into which my guide plunged a piece of money, closed entirely about it, and formed a specimen which I still have in my possession. The beholder is fascinated by such a grand display, its novelty and unearthliness taking away all sense of fear. It was not, however, altogether safe, as the red-hot masses might come upon one in a shower from which there could be no escape, and a sudden change of wind might surround the watcher with a suffocating gas.

The sun had now disappeared, and it was so dark from steam and clouds that the guide thought it prudent to return. We had no lanterns, and pursued our way almost at random, guided only by the shouts of those below us. We passed over some very ugly crevices, so hot as to be uncomfortably felt even through thick-soled shoes. The road is easy enough by day, but by night sight is impossible, and the senses of hearing, smell and touch, and trust in Providence, must suffice to bring the pedestrian back to the path.

The journey would hardly be a safe one for ladies and invalids at any time of extraordinary activity. The night of our ascent was the most active for several weeks. I saw no flowing lava, but it could be seen on the opposite side of the rim, by making a long and difficult détour, impossible after dark, and always dangerous from the changing gas currents.

ON THE SUMMIT OF MT. VESUVIUS.

Two days before our visit a lady came very near losing her life from suffocation, and was with great difficulty restored from a state of unconsciousness. This, however, was probably her salvation, as it checked the action of the lungs and heart. The danger was occasioned by a sudden change of wind which blew so strongly to the west that the smoke was unable to rise. It settled along the valley in which the railroad runs, and extended nearly to the sea.

The grandeur of this outburst can only be appreciated after dark, when few persons contrive to see it. The ascent is not fatiguing for an average walker, though the rarefied air and sulphurous fumes are at first disagreeable. The light at the summit, seen occasionally from Naples, is the reflection or illumination of the white smoke by the jets of lava beneath. The display that I witnessed is not visible at Naples, on account of the distance of the eruptive cone from the edge of the great crater. As we approached the base the moon appeared nearly full, and the view of mountain, plain and sea was exceptionally fine, even for Naples. — 1882.

The Vesuvian railway ascent is less exciting, and apparently less dangerous than that of Mt. Washington or the Rigi, but far more interesting from the black, ash-covered lava, over and by the side of which it passes. As an exhibition of the subterranean forces of nature, I regard an ordinary Vesuvian summit display as equal to that of Mayon, and inferior to the "Lake of Fire" at Kilauea.

The edge of the great cone, within the partly encircling ring of Somma, is about a thousand feet high. It was built up by its own ejections during the last eighteen hundred years. During this period it has been several times destroyed and re-

formed. The lavas of Somma differ from those of Vesuvius, the strata being regularly inclined at an angle of twenty-five to thirty degrees, and the sides covered by layers of tufa inclosing marine tertiary shells, indicating that, like Etna, it was once submarine, and that the Italian, like the Sicilian shore, has undergone many hundred feet of elevation during the preceding and present geological ages.

A careful comparison of the volcanic products of Japan, the Philippines, the Malay Archipelago and the Mediterranean, as well as of the Hawaiian Islands and Iceland, forces the conclusion already reached by the chemical geologists, that lavas, from whatever locality, are one half oxygen, one fourth silicon (acting as an acid), one tenth aluminum, with magnesium, calcium, iron, sodium and potassium in varying proportions, and all from sources far beneath the surface. The more silicated ones, or the acid, like trachytes, are lighter in color and in weight than the basic or basalts, which have less silica, and much more magnesium, lime and iron; they are, however, poor in soda and potash.

A thick lava stream may take many years to cool. I have walked over a floor in Kilauea, apparently old and cold, but in the crevices of which the end of a cane would be burned, even when the material of which it was made was a very poor conductor of heat. Prof. Judd states that masses of snow, covered by a thick layer of scoriæ in the Vesuvian eruption of 1872, and subsequently by lava, were found three years after consolidated into ice, and not melted. It is said that Catania is supplied with ice from the snows buried by the ejections of Etna.

The chemical study of lavas has thrown much light on the

character of the granitic rocks, which were once supposed to be peculiar to the oldest geological ages. Granite is now recognized as the crystalline representative of lava, consolidated under the immense pressure of great depths. Syenite and diorite have the same chemical composition, differing only in form. The great granite masses are, according to Prof. Judd, the "cooled reservoirs from which volcanoes have in all probability been supplied during earlier periods of the earth's history." In the same deep recesses, with high temperature, intense pressure, superheated steam and acid gases, carbon becomes the crystallized diamond; alumina, the ruby and sapphire; silica, the amethyst, emerald, and topaz.

The precious metals have been placed within man's reach by volcanic agency, brought up from the depths; the agate, the onyx and the zeolite crystals have a similar origin. The conclusion seems justified that granite belongs to all geological epochs.

To understand the causes of volcanoes it should be remembered that they occur along great lines of fissure in the earth's crust, and, with the present exception of the Sandwich Islands and Thibet, near to the limits which separate the great land and water masses of the globe; that is, near the coast line, or on islands not far from the shore. According to Lyell, almost all active volcanoes are on rising areas, and are notably absent from those undergoing depression.

CHAPTER VII.

ETNA AND STROMBOLI.

Interest of Stromboli.— Theory of volcanoes derived from its study.— Picturesque railway to Catania.— Etna.— Immense lava flows.— Varied outline, depressions, and summit.— Monti Rossi.— Difficulty of ascent.— Observatory.— Magnificent view from summit. Great eruptions of 1669, 1852–53, 1865, 1874, and 1879.— Crater in 1882.— Age and origin. — Fertility of lava soils, and utility of volcanoes.

IN March, 1882, on the way by steamer from Naples to Sicily we passed near Stromboli, a volcano which has been in constant activity for two thousand years. Other smoking peaks in the west, among them Vulcano in the Lipari Islands, were plainly to be seen, and in the distance on the eastern extremity of the island loomed the cloud and snow-covered peak of Etna.

As a volcano Stromboli is insignificant; but it is of great interest as the one which, by the careful observations of Spallanzani and others, led to the present understanding of volcanic phenomena. Its action is not generally violent, but its cone, three thousand and ninety feet high on the line between Italy and Sicily, is a prominent object. When in eruption it is a beacon on a grand scale with its glare of red light, without flame, the illumination of its watery vapors from below, flashing from time to time, increasing and fading at irregular intervals. Its mass beneath the sea gives to it a total vertical height of at least six thousand feet, with a base under water of more than four miles; it has been built up by its own ejected matters,

which resemble the refuse cinder and slag of a huge iron furnace.

Action has apparently ceased in the central and summit crater. A new one has opened on the northwest side, about one thousand feet below the top.

I saw Stromboli both by day and night at a week's interval, but it gave forth only vapors which formed a cloud that floated off with the wind, and were made up of rounded masses, each from a volcanic jet, like the rings from the smoke stack of a locomotive, or from the mouth of a smoker. The eruption is from a circular depression two thousand feet above the water, whence a flat slope of thirty-five degrees, with steep walls, extends to the sea. Here Spallanzani, in 1788, and later, made the examinations which, extended and confirmed by others, led to the work of Scrope in 1825; the first systematic treatise on the subject.

Prof. Judd, in his work on "Volcanoes," describes a visit to this volcano, April 24, 1874, when he saw one of its occasional outbursts from a point whence he could look directly into the crater. With a noise which he describes as like blowing off steam, he says that "a great volume of watery vapor was at the same time thrown violently into the atmosphere, and with it there were hurled upwards a number of dark fragments which rose to the height of four or five hundred feet;" the most of these fell back into the crater with a loud, rattling noise, but some were thrown outside, and went rolling into the sea. The study of the phenomena renders highly probable his explanation of a volcano as a "great natural steam-engine," whose supply we can neither control nor lessen, the active cause being the escape of steam from masses of molten rocks. The violence of the eruption depends on the amount and tension

of this escaping vapor, sometimes with the pressure due to great depths.

He saw here the puffs of steam, the movements and overflow of fluid lava, and the bursting of gigantic bubbles of the viscid material, carrying into the air the fragments of the scum-like surface or glowing masses of semi-molten rocks. There was no flame, he says, the light being the reflection of the fiery liquid on the clouds of vapor above.

Prof. Judd declares that the popular definition of a volcano as "a burning mountain, from the summit of which issue smoke and flames," is not correct. Volcanic action, he says, is neither burning nor combustion; volcanoes are openings in the earth's crust, and only become mountains by the piling up of their own ejected materials. The eruption may occur at any part of their sides or bases, as in Kilauea, and the smoke is condensed vapor, while the flames are simply the reflection of the glow of the molten, and not burning, matters on the floating clouds over the crater. Of course inflammable substances are occasionally formed within a volcano; these may take fire, and produce real, though feebly luminous, flames. But the sulphur found in volcanic regions is the result, and not the cause, of volcanic action. The whole story of the grand and the feeble outbursts of a volcano may be referred to a simple cause: "the escape, from the midst of masses of molten materials, of imprisoned steam or water-gas." The island of Sicily was undoubtedly once connected with Italy.

The railway from Messina to Catania, at the base of Mt. Etna, — a journey of two and one half hours, — is one of the most picturesque in Europe. It winds along the shore, with the blue Mediterranean on the left, and high cretaceous or

volcanic cliffs on the right, — piercing the promontories by tunnels, crossing mountain streams, cutting through beds of lava, — at every turn opening to view a ruined castle, or terraced vineyards and orchards, and always with hoary-headed Etna looking down on all.

The volcano of Etna is on the east side of the island. It is eleven thousand feet high, with a circumference, at its base, of nearly one hundred miles. A part of this base extends to the sea thirty miles distant. The angle of inclination, until near the summit cone, is, on an average, twenty degrees. The sides of the mountain are dotted with one hundred and seventy-five smaller cones, many deserving the name of mountains. The outline of the upper portion is regular and clearly defined, and the central crater is always emitting clouds of vapor and gases. Etna is the largest of the European volcanoes, and some of its lava flows have been immense; one, in 1669, overwhelmed Catania, twelve miles distant, and reached the sea. There are some marks of these on the mountain itself, displaying a black sterility seven to eight miles long, and more than a mile wide.

As in other cases, the huge mass of Etna has been built up by its own ejected materials. Before the eyes can take in the dark outline of the ragged sides and smoking summit, they rest with pleasure on the smiling villages, vineyards, and forests, which cluster on its flanks. Even in March, when I saw it, though the cone was covered with snow, around its base was perpetual verdure. This emerald green, with its outer setting of the sapphire-blue of the Mediterranean, made a splendid contrast with the dazzling white which crowned the peak. This cultivated region is about ten miles wide, and extends to a height of over four thousand feet, but at two thousand the

growth of orange and lemon ceases; at thirty-three hundred there is only the apple among fruit trees, and at four thousand feet the vine disappears. Between this and the altitude of six thousand only wild vegetation remains. Six or seven miles of space contain the chestnut, oak, cork, beech, and pine-tree growths, but these gradually diminish in size and number to the height of sixty-six hundred feet, where only the hardiest plants survive, and beyond the altitude of ten thousand feet there is nothing but cinders, ashes, and ice.

At the height of about ninety-six hundred and sixty feet, the cone is interrupted on the south side by a platform, covered with black sand, nine miles in circumference, limited by volcanic rocks and craters; the "*Piano del Lago*," from which arises the present eruptive cone of over thirteen hundred feet. On the eastern side is the "Val del Bove," a depression six miles long, three wide, and three fifths of a mile deep. This immense amphitheatre, surrounded on three sides by high precipices, is open to the east, and is looked directly into from the town of Giarre. This break is generally believed to have been produced by a sinking in of this part of the mountain. The rocks around it are almost all composed of numerous horizontal layers of lava, interspersed with masses of scoriæ, and earthy matters. These lavas differ from the ordinary dark ones of modern Etna in being of a reddish, yellow, and violet color, often containing large crystals, and traversed by veins of more recent eruptions, and of varying chemical constitution, as if, during the rending of the mountain, the resulting fissures had been filled with the new liquid matters, either before or after the upheaving of the main cone. Elie de Beaumont explains this depression by a sudden upraising of the central portion, which caused a rupture

only on the eastern side; but Lyell, Hoffmann, and Waltershausen, noticing a slight inclination of the surrounding strata to the southwest and north, regard it as due to a subsidence of the east flank.

According to Lyell, the present active centre is nearly four miles from its earliest position. Gemmelaro is of opinion that where now is the Val del Bove was once the eruptive axis, and that the summit fell into the interior of the mountain, as happened in 1779 to Papadayang, the largest of the volcanoes of Java. It would seem, therefore, that the volcano of Kilauea, on the side of Mauna Loa, in the Sandwich Islands, at a height of four thousand feet, on a mountain of fourteen thousand, and the great chasm of the Yosemite Valley, California, can best be explained by a similar falling in, consequent on great subterranean dirturbance, and that ice and water, in the latter case, have had very little to do except in slightly rounding and polishing projecting points.

The ascent of Etna can only be made between July and October, and is at best a difficult task. Whether the start is made from Catania, or Aci Reale, the first day's work is to reach Nicolosi, twenty-four hundred feet above the sea, a village of about twenty-seven hundred inhabitants. Whichever direction is taken lava streams must be traversed, most of them old and covered with vegetation, with many pretty villages on the route. During the first hour's journey the hills are covered by a layer of clay, sometimes containing shells, indicating the presence of the sea at a remote period. After the second hour the road becomes more steep, running between the lava flows of 1408 on the right, and of 1669 on the left. In two and one half to three hours Nicolosi is reached, and here arrangements for the

climb to the summit are completed. After making the ascent of the Monti Rossi, at the foot of which the village is situated, the night is passed in a comfortable hotel. It is in the middle of a plain of cinders, and is rather dismal-looking because of its lava-built houses.

Monti Rossi is a good example of the secondary or parasitic cones, of which there are hundreds on the sides of Etna, marking its regular outline. These scoriæ cones, formed along fissures in the primary one, were originally really black, but became reddish by the oxidation of the magnetic oxide of iron, which is found in almost all lavas. It is this color that has given its name to the Monti Rossi. Its cone, which appears double from the sinuosities of the edge of the crater, is nearly two miles in circumference, and eight hundred and thirty feet above Nicolosi, or thirty-two hundred and thirty above the sea. It is one of the largest craters on the mountain, and consists of very friable lava, containing many crystals of pyroxene or augite. There are several other craters along the line of fissure, at the bottom of one of which opens a series of caverns, ending in a large grotto, discovered by Mario Gemmelaro, in 1823. It was formed in 1669, when two great gulfs opened during an earthquake; from these there issued such an amount of scoriæ and sand that this cone was raised in three months. One of the three streams of accompanying lava flowed fourteen miles in six and one half weeks, to the edge of the sea, a larger one descending to Catania. These appear quite recent, and are, for the most part, dark and sterile. This alternation of the eruptive action from the summit to the sides has been frequent in its history; the former adding to its height, the latter to its bulk.

It is the custom to start from Nicolosi, on mule back, early in the morning of the second day. A guide, obtained at an expense of two dollars, is necessary, and as much more is to be expended for a mule and driver. Half a dollar pays for lodging in the "Etna House," at the base of the cone, and a small sum for each mule. For long excursions the tariff is generally one dollar a day for mule and driver, and seventy-five cents for each guide. The prices are fixed by the Italian Alpine Club, and the men are capable and trusty.

The first mile is over a plain of black sand, ejected from Monti Rossi in 1669, in which flourish some vines and fig-trees. The lava of 1737 is soon reached, and the ascent is now between two lines of old craters or mountains, from six hundred to one thousand feet high, and largely covered with vegetation. Passing through another group of similar cones, in two and one half hours the traveller arrives at the Forest House (Casa del Bosco), a farm at the foot of Monte Capriolo, over four thousand feet above the sea, and higher than the summit of Vesuvius; here travellers take rest for breakfast.

Beyond this point the ascent becomes steep, and the air chilly. Plant life dwindles and disappears; the desert begins, and the region of glaciers is attained. Before coming to the ice the Goat's Cavern is passed — in a thick layer of lava, five thousand three hundred and sixty feet above the sea. This was a convenient resting-place before the erection of the "House of the English," in 1811, by officers of that nation. Meeting there the lava of 1766, and traversing a third group of cones, the flows of 1780 and 1763 are crossed. Here the bright-red cone of Montagnola is a conspicuous point on the south flank. Climbing now begins in earnest, and the mules

can hardly carry their burdens. After a time a vast plain of dry black sand, seven miles in circumference, is reached, from which arises the grand cone, at least one thousand two hundred and fifty feet high. The dark and barren surroundings, the strange shapes of the rocks, the solitude and the silence of this cold desert are depressing, and one sees with joy the "Etna House" and Observatory, after a hard day's work. This is at the very base of the cone — nine thousand eight hundred feet above the sea — and rarely, if ever, visited for one half of the year.

The Observatory is of two stories, in all thirty feet high, occupying an area of about six hundred and fifty square feet. In the centre of each story is a large circular room with small ones surrounding it. In the lower story is the column for the telescope, which is placed in the upper, its lens having a diameter of 11.2 inches, covered by a movable iron dome. It is placed on a small cone, which, judging from the past, will protect it from the lava in case of eruption, as the streams always flow on the opposite side of the volcano. The Vesuvian observatory is only two thousand and sixty-five feet above the sea; the Hospice of St. Gothard six thousand eight hundred and fifteen; of St. Bernard eight thousand three hundred. For a long time this latter was the highest inhabited spot in Europe; but the observatory on Etna is one thousand five hundred feet higher. The "Etna House," an annex of the Observatory, is an enlargement of the old "House of the English," and can accommodate a dozen persons; travellers stop here to dine, and to pass a part of the night. Food is brought and prepared by the guides. The arrival is before sunset, and the panorama of mountain, forest, field and sea is extensive and magnificent beyond de-

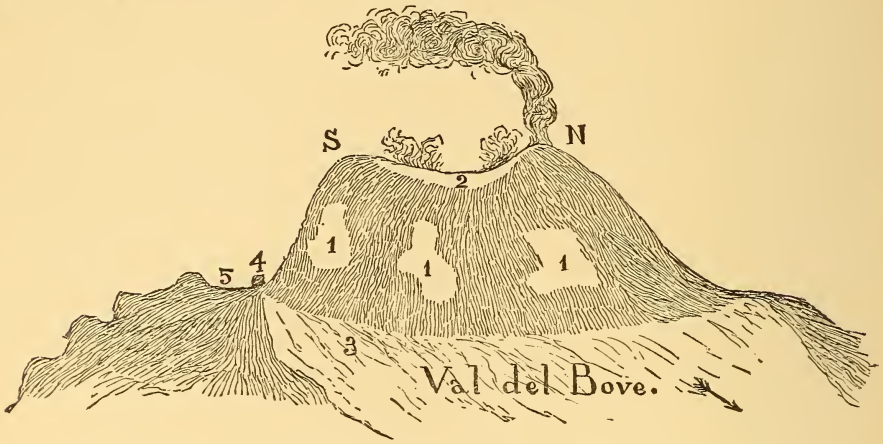
scription. It embraces the coasts of Sicily, as far as Malta, and, in a clear day, the African shores; the sun shines on the summit after the plains are shrouded in darkness, and the effects of light and shadow are wonderful. The air is chilly even in summer; it is near the freezing point, and the fire in the chimney of black lava is very necessary.

One hundred and seventy-five feet below the Observatory is a ruin about twenty-five feet square, called the "Philosopher's Tower." Tradition declares it to have been inhabited by Empedocles, who, 400 B. C., pretending to be a god, and, in support of his claim, plunged into the volcano, that his body might not be found; but the ejection of one of his brass sandals unfortunately revealed the deception. It is, however, much more likely that it is the ruin of the hut erected by the Emperor Hadrian, when he ascended Etna in the early part of the second century.

The mules must now be left, and the ascent made on foot, beginning the journey soon after midnight, by the light of torches or the moon. The stream of 1838 is soon reached; steam is seen issuing from numerous cracks, and at the bottom reddish reflections are noticeable at night. The crater-cone varies from one thousand to one thousand two hundred feet in height, and is difficult of ascent on account of the scoriæ, ashes and sand which yield beneath the foot; the ascent is possible only by following the flow of 1863. An hour's climb brings one to the summit, at the south edge of the crater, the surrounding rocks being very hot, with abundant emissions of steam and sulphurous gases. By watching an opportunity, when the wind is favorable, one can get, stretched on the rocks, a peep into the immense gulf, though ordinarily nothing can be seen but a

dense vapor, more or less illuminated by the molten masses below.

As I saw it from between Aci Reale and Nicolosi, in March, 1882, the outline of the crater was as follows: —



SUMMIT OF ETNA, MARCH, 1882.

Smoking all along the upper ridge, but most on the north side.

1. Apparently patches of snow.
2. White; probably incrustation around edge.
3. Val del Bove; arrow pointing to Giarre.
4. Observatory.
5. Piano del Lago.

If the sunset from Etna is magnificent, sunrise is even more striking, as the sun appears at the summit while night reigns at its base and on the opposite side. As the light chases away the darkness, the effects seem like natural magic on an immense scale; cones, before invisible, come into view like black monsters, and the flanks bristle with secondary volcanic ridges and craters, which impair its symmetry, while increasing its grandeur from above.

The form of the crater has changed much within the last four centuries. In 1444 the central cone fell in; in 1537 a new one was formed, which was destroyed in 1669; in 1744–45

another appeared, the southern segment of which sank down in 1756, and is recognizable at the present time. Before 1879, the crater was about four thousand three hundred and thirty feet in circumference, oval in form, its greatest diameter being one thousand five hundred feet, and, as the eruption of that year sent forth only gases and ashes, it probably has about these dimensions now. According to Silvestri, who is to Etna what Palmieri is to Vesuvius, it was at that time possible to descend into it, the bottom consisting of scoriæ and lava at a depth of two hundred feet. Since then it has not been entered. This surface was dotted with white, yellow and red incrustations, and in the middle opened a vast pit, some two thousand feet in circumference, in which could be seen and heard the movements of the liquid matters agitated by the escaping gases.

The violence of Etna's eruptions was known long before the Christian era. The earthquakes, fissures and lava flows were, by the old myths, attributed to the struggles of the rebellious giant Typhon, who was overthrown by the thunderbolts of Jupiter, and buried beneath the volcano. In the Middle Ages its fires were looked upon as the place of torment of Anne Boleyn, the Protestant queen of Henry the Eighth, and the mother of Queen Elizabeth. As in other volcanoes, subterranean noises, earthquakes and volumes of smoke and vapor, precede in Etna the ejection of stones, scoriæ and lavas, either from the summit crater or rents in the sides. The stream in its progress fills valleys, obliterates rivers, burns up the forests and dwellings, and overwhelms fields and villages. Flowing ordinarily at the rate of seventeen to twenty feet in a minute, the crust hardens quickly, its glassy surface cracks continually, and its rolling masses clink together with a dull metallic sound.

The most terrible of the earthquakes accompanying an eruption was in 1693, from the eighth to the eleventh of January. Houses fell by hundreds in Catania, the sea penetrated the city, the vessels in the harbor tossed against each other, the bells in the churches were rung, and the cries of thousands of victims mingled with the internal rumblings, the roar of the waves and the detonations of the mountain. The city was reduced to heaps of ruins, and at least sixteen thousand persons perished.

In 1669, twenty-four years before the above, occurred the greatest eruption of modern times; on the eleventh of March, after three days of tremblings, a huge fissure opened on the south side. It was twelve miles in length, beginning about a mile below the summit, and bordered by many small craters near Nicolosi; a lava torrent, more than a mile wide, issued from these numerous craters, advanced rapidly toward Catania, and destroyed two mountain villages. It then met with an obstacle, and divided into two branches: one, one third of a mile in width, greatly damaged three hamlets; the other, which had acquired a breadth of nearly two miles, went toward Belpasso, and there meeting an obstruction, again divided into two, the smaller flowing a little more than a mile, and the larger, a mile wide, passing rapidly toward Catania. In a few hours the lava filled a small lake and its inclosing valley, and in five weeks reached the western boulevard, surmounted a wall sixty feet high, covering many of the ancient ruins, filled the streets of that section, and completely surrounded the old castle of Ursino. In two weeks more it began to throw itself into the sea, with a width of one half of a mile, and a thickness of forty feet. The flow advanced thirteen miles in three weeks, but only twenty-two feet an hour for the last two miles toward the water;

it retained a great heat for eight years after. Fourteen villages were overwhelmed, and the earthquakes destroyed all the houses in Nicolosi. The cone of Monti Rossi was formed at this time, in three months; it gave forth seven hundred and sixty million tons of lava, covering a surface of nearly nine thousand five hundred acres, a considerable part of which was productive soil.

The summit eruption of March, 1755, is geologically of great interest, as the sudden melting of the accumulated snow and ice caused a flood to pour through the Val del Bove to the sea, in a channel one and three fourth miles wide, and over thirty feet deep, conveying sixteen million cubic feet of water, — the estimated volume in a mile, — carrying an immense amount of loose materials, in one and a half minutes, for more than twelve miles. This not only did no important excavating work, but really filled up the lower part of the valley, contributing largely to the coast deposits in the vicinity of Giarre.

The eruption of 1852–53, though but slightly destructive, is the largest on record, except that of 1669, and that of Mojo, 400 B. C. It began August 20, 1852, and continued until May 27, 1853 a period of more than nine months. The united width of the lava streams was two miles, with a depth from eight to sixteen feet, piled up in some places to one hundred feet. It reached to near Zafarana, — almost six miles, — descending thirty-five hundred feet in sixteen days. The Val del Bove, from the upper part of which it proceeded, looked like a sea of fire. Explosions, as of artillery, were frequently heard, and the scoriæ were sent up to great heights. The summit sympathized with the lateral openings, and emitted enormous volumes of vapor, ending in a white incrustation which is still to be

seen, and has the appearance of snow. The heat was such that trees at a distance of several feet took fire.

On the evening of January 30, 1865, the mountain was rent on the northeastern side of its middle portion, and sent out a torrent of lava which grew by degrees to a width of one and one half miles wide; it filled up a large valley, and, after a course of eight miles, was arrested at a height of about twenty-seven hundred feet above the sea. Seven craters formed along the fissure, in violent eruption, the materials rolling like blocks of ice in a river, and forming lateral and terminal moraines, as in a glacier.

On the twenty-ninth of August, 1874, a large fissure opened on the north side, and an eruption, which threatened to be a grand one, commenced; but it diminished on the second day, and very soon ceased. Along its path, at the bottom of which Prof. Silvestri saw the glowing lava, more than thirty scoria cones were thrown up. After this abortive attempt Prof. Silvestri prophesied that the next eruption would be along the line which remained open; a prediction which was fulfilled on the twenty-sixth of May, 1879.

During this eruption the shock of the fused matters was so great that it produced on the opposite, or south-southwest side, a fracture three thousand feet long and one hundred feet wide, at an elevation of more than two thousand feet above the north-northeastern opening; presenting the singular phenomenon of an eruption on both sides of the mountain. Two small streams of lava issued from it, which passed through fifteen feet of snow, but stopped on the next day, after a course of little more than a mile. The volcanic activity then concentrated itself on the lower opening, from whose numerous craters was ejected a torrent one thousand feet wide, which flowed rapidly toward

Mojo, a small village on the north-northeast base of Etna. At the same time there was a dense shower of ashes and sand, which extended over an area of eighteen miles. Advancing at a rate of twelve to sixteen feet in a minute, on the morning of the twenty-eighth it had passed over four miles, burning thousands of pines and oaks. By night it had crossed the national road, following the course of a mountain stream whose bridge it destroyed. The fright of the people was extreme, but of short duration, for its progress became slower; from eight hundred to two hundred and fifty feet a day. It finally stopped two thousand feet from the river Alcantara. The flow was six miles long, with an average width of one quarter of a mile. On two of the secondary craters was formed a conical, double-cratered mountain, six hundred feet high, called Umberto-Margarita, in honor of the king and queen of Italy. Four groups of smaller mountains were also formed. This eruption lasted eleven days, and gave issue to nearly twenty-three and one half million tons of lava, covering a surface of about seventy-five acres.

The crater, as I saw it in the middle of March, 1882, was very much as it was left after the eruption of May and June, 1879. Vapor was rising apparently from almost all the south rim, in a crevice running from west to east, but originating so far below the edge as to leave the outside patches of snow unmelted. The white, snow-like appearance near the upper portion may have been the white incrustation above alluded to. The edge could be clearly traced far to the northeast, and the whole surface in that direction seemed to be smoking.

Etna, or Mongibello, has had two permanent craters of eruption, like Mauna Loa and Kilauea in the Hawaiian Islands, and Somma and Vesuvius; the smaller was in the middle of what is

now the Val del Bove, which was the result of depression and not of upheaval; the "Piano del Lago" is probably a filled-up crater. The alluvium at Giarre is ten miles long by three wide, and more than one hundred feet thick, and is proof that aqueous denudation has considerably modified it since the paroxysmal explosion of the old cone on the side and engulfment. This was, probably, toward the close of the glacial period, when the ice was much more extensive, and would afford ample source of aqueous denudation. Aërial disintegration must also have exerted a powerful influence in this elevated valley, which embraces about one sixth of the great mass. It now contains no cattle, as its name would import; a few goats clamber about its lower precipices, and vegetable life is represented chiefly by the yellow ragwort and autumn crocus (*colchicum*).

According to Prof. Lyell, the chief mass of Etna, or that of sub-aërial origin, is of the post-pliocene age, its foundations being laid in the sea which then covered the present site of the mountain. This was raised by the outpouring of lava and scoriæ, and the slow uprising of the whole region, and may thus explain the presence of marine shells in tertiary strata many hundred feet above the sea-level.

The last recorded eruption of Etna was in May, 1886. This came near overwhelming Nicolosi. The great lava stream moved at a rate of one hundred and thirty-five feet an hour, and came within half a mile of the village; the inhabitants fled, terror stricken; several dwellings were destroyed, but no lives were lost.

According to M. Fouqué, the temperatures at which certain chemical deposits and vapors are produced at Etna are as follows: — At the highest heat, which is sufficient to melt copper

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and silver, there are the alkaline chlorides of soda and potash; at the melting point of zinc, chlorohydric and sulphuric acids, with watery vapor; at two hundred and twelve degrees Fahrenheit, or a little over, steam, with sulphuric acid and sulphur; and lastly, as in the ordinary state, pure water.

As one travels among this volcanic scenery, it is strange to see by the side of, or amidst the lava flows, vines, oranges, lemons, and almonds, growing luxuriantly. Every stage of soil development may be traced from utter barrenness to fertility, and the humble natural instruments may be recognized by which this beneficent change is commenced and carried on. As soon as disintegration of the lava from the action of the elements begins, reddish-yellow or orange lichens (*stereocaulon*) appear in large patches; then seeds of weeds and grasses, brought by birds and winds, vegetate; cacti, large and fleshy, follow, naturally, or planted by man, in every favoring crevice; and hardy shrubs and bushes here and there find sustenance. With the aid of frost, snow, sun and rain permeating the porous surfaces and oxidating the iron, the roots break up the crumbling lava, and finally reduce it to powder; man adds fertilizers, and waters brooms and plants which annually decay, and in the course of a few years the rugged, desolate lava becomes a grass plot, a vineyard, or a lemon orchard. Hundreds of these little oases in the desert, with a very black and productive soil, are seen in the course of a mile; giving to the base and lower sides of Etna the semblance of verdant fields. Many and populous villages dot the flanks of the volcano, in what would seem to be dangerous situations, verifying the saying of Buffon, that wherever man can get his daily bread, he will be found, even in presence of daily peril.

Volcanoes are, therefore, not wholly bad, and are by no means so destructive as is popularly believed; life is rarely sacrificed, and ample time is generally given for escape and the removal of valuables. Japan and Java, populous and productive, are over volcanic centres. Between the two rivers which inclose Etna live three hundred and thirty thousand people; nine hundred and sixty-five to a square mile; six times as many as in any other part of Italy. The soil at the base of Vesuvius is the most fertile in Europe; surpassing the suburbs at Paris, and equalled only in the vicinity of New York. These "smoking hills" are, therefore, rather preservative than destructive, as they prepare the undermined crust of the earth to follow down upon the shrinking and cooling centre, by local, rather than widespread, convulsions.

During the year 1887 Etna has been, at irregular intervals, more active than usual; but nothing deserving the name of an eruption has been chronicled.

CHAPTER VIII.

PHILIPPINE ISLANDS. — TAAL, MAYON, AND TIBI GEYSERS.

Volcano of Taal. — Volcano of Mayon. — Its symmetrical shape. — In eruption for more than a year. — Beautiful both by night and day. — Native fear of it. — Various unsatisfactory attempts to ascend it. — Its chief eruptions. — Catastrophe of 1814. — Geysers at Tibi. — The red and the white cones. — An uncanny spot. — Silicious incrustations. — Usual causes.

IN January, 1882, in company with the American Consul, I visited the district of the Laguna, or Lake of Bay, southeast of Manila, the capital of Luzon, the largest of the Philippine Islands. The trip was by steamer up the Pasig River.

One of the stopping places is Calamba, the point of departure for visitors to the Lake of Bonbon and the volcano of Taal, distant over land some twenty miles. Usually, long before the lake is visible, volumes of white vapor are seen rising above the surrounding hills. The lake is about seventy miles in circumference, oval, mostly inclosed in high, wooded land, with here and there overhanging cliffs.

The island of Volcan is in the centre of the lake, and was doubtless upheaved during a volcanic convulsion. It presents a very ragged and timeworn appearance. The approach from the north is amid some fine mountain scenery. The island is reached after a two hours' paddle over its ashy, still waters, which are not very palatable from their iron, volcanic taste.

The volcano is very difficult to climb, as it is a mass of yield-

ing cinders and sharp clinkers from bottom to top, of every size and shape, and it is rent by dangerous chasms and precipices. It is one thousand two hundred feet high, and a good hour's climb. The oval, ragged rim of the crater is six miles in circumference, with precipitous sides of unmeasured depth. In the bottom is a black pit, about five hundred feet in diameter, and a sulphurous lake constantly emitting suffocating, but invisible fumes. Its descent, of many hundred feet, is dangerous.

Dr. Kane, the Arctic explorer, very nearly lost his life in attempting to descend this crater, and was only drawn out by ropes, fortunately attached to him, in an insensible condition. The air is so clear within the crater that small objects can be distinctly seen through the azure, and, doubtless, sulphurous atmosphere. It was not visibly smoking during our visit to the Laguna.

In the latter part of December, 1881, I found myself on board a steamer bound from Iloilo to the island of Luzon in the province of the Camarines, and especially to that part of the island known as Legaspi, on the eastern side of the peninsula on which the volcano of Mayon is situated.

We had the first sight of the mountain of Mayon on the western side, at Donzol, watching it until late at night, when the view was cut off by the high lands around which we were to sail. We passed through the Straits of San Bernardino to Legaspi, and by daybreak we had rounded the point where we again beheld Mayon to the west of us.

There is something grand in this symmetrical peak, a typical volcano, rising over seven thousand feet from the water's edge, and displaying here, on the verge of the Pacific, its pillar of

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cloud by day and its pillar of fire by night. It is the beacon of the mariner coming westward from Polynesia, with no land to the east nearer than the Ladrone or Marianne Islands, over one thousand two hundred miles away.

Landing at Legaspi we rode to Daraga, a few miles distant, to get the nearest and best view of the volcano, and to see the traces of the great eruption of 1814, which destroyed the old town, then situated higher up the mountain. The new town of Daraga is within five miles of the base of the mountain; near it are the remains of the church, and other buildings then overwhelmed, their ruins projecting from the masses of rocks and ashes. Pieces of lava, six feet in diameter, were thrown from the crater to a distance of five miles.

During our Christmas dinner the summit was all ablaze, and presented the most magnificent volcanic exhibition I ever witnessed. It was neither so awe-inspiring as Kilauea, nor so terrible as the fiery shower at the top of Vesuvius, already described; but it was majestic in the distance which assured safety, sublime in its altitude, and glorious in its constant outpouring of red-hot lava which trickled down its side like a cataract of fire. We had rare glimpses of the summit during the day, which was cloudy, but at night could only see the lurid glow which showed that the cauldron was still running over.

During the forenoon a crack opened on the Legaspi side, considerably below the top. From this was sent out an immense quantity of white smoke or vapor, and clouds of ashes which settled near its source. During the night there was a hardly perceptible earthquake trembling; but these disturbances are very common, though severe ones are rare, perhaps on account of the proximity of Mayon's safety valve.

The cone of Mayon is one of the most symmetrical in the world, both to the naked eye and through a glass; its lavas are mostly felspathic, being doleritic, like those of Etna. I obtained and brought home many characteristic specimens of the old and the new lava, taken from as high up the mountain as the barefooted natives could go.

By day I could detect no movement, as this was chiefly beneath the rapidly-cooling external crust. I could see only the curling, light-colored vapor; the black lava, apparently still; calcined reddish-white and yellowish rocks; and beds of grayish cinders of considerable size and great steepness. Green vegetation extends far up, and in pointed tongues, amid the desolation of the peak, where it is not destroyed by the heat or rendered impossible of growth by lava.

At night the scene was truly magnificent and unique. At the date of my visit the volcano had poured out, for five months, continuously, a stream of lava on the Legaspi side, from the very summit. The viscid mass bubbled quietly but grandly, and over-ran the border of the crater, descending several hundred feet in a glowing wave, like red-hot iron. Gradually fading as the upper surface cooled, it changed to a thousand sparkling rills among the crevices, and, as it passed beyond the line of complete vision behind the woods near the base, the fires twinkled like stars, or the scintillations of a dying conflagration. More than half of the mountain's height was thus illuminated.

Mayon has always been an object of superstitious fear to the natives, and a welcome light to the old Spanish galleons with their freight of silver from Acapulco. To remove the dread of the Indians, it was visited in 1592 by two Franciscan monks,

one of whom, Estaban Solis, is believed to have nearly, if not quite, reached the summit. At all events he ascended as far as the suffocating gases permitted, and far enough to satisfy these simple children of Nature that there dwelt in the fire mountain no evil spirit who could injure them. This fear removed, the natives came to the priests for baptism, and thus was laid the foundation for the Christian civilization of the district. It was literally a baptism of fire for the monk, for, though he returned apparently unharmed, he fell sick and died within a year after his terrible experience.

It is stated that two young Scotchmen ascended to the crater in 1858. They found the task a very difficult one, as the steep cone was one mass of sand and cinders, interspersed with ragged clinkers and lava. They do not claim to have been there more than three minutes, on account of the sulphurous gases, and it is scarcely probable that they saw down into the crater, as they do not describe it. Then, as now, the ruddy glow of night gave place by day to the black and sombre colors of the lava, surmounted by the white vapor.

Jagor, in 1859, recounts the incidents of his ascension, stating that in eight hours, after leaving the height of one thousand feet, where he passed the night, he attained the summit. He found, beyond his starting point, a luxuriant vegetation, which gradually diminished to lichens, and above these was the naked rock. The top was cracked in all directions, emitting suffocating vapors, which compelled him to close his nostrils and mouth with his handkerchief. Though he could not look into the crater, he believed he was on its edge. He stood upon a layer of hard rock, which was about two feet thick, and covered with scoriæ blanched by the action of sulphurous gases. Many irreg-

ular blocks of this had evidently formed a higher point of the peak.

From the side opposite Daraga there had flowed a stream of lava, the surface of which consisted of such fine and spongy material that it looked like a carpet of moss. At my visit the cone appeared sharper in its uppermost portion than is portrayed on any representation that I have seen. In the rainy season good views of the volcano are rare, as, from its size and height, it arrests the clouds from the Northeast Pacific, and these pour their contents in hundreds of rills from its blistered sides.

The first historic notice of its eruptions is that of 1616. The first destructive one was on October 23, 1766. It completely overwhelmed Malinao, and did great damage to the neighboring villages. It began on July 20, lasting six days, with a pyramidal light gradually diminishing. From the summit a stream of lava one hundred feet wide, descended for two days to the east; on the twenty-third of October such a quantity of water was discharged, apparently from the volcano, but, probably, from some other source, that rivers eighty to two hundred feet wide rushed down its sides to the sea with such violence as to set back the in-coming tide. A furious tempest raged from seven P. M. to three A. M., from northwest to south, washing away the roads, and was, no doubt, the source of the water attributed to the volcano. I do not think there is any well-authenticated instance of a volcano throwing out water, except as this results from heavy rains, from melting snow or ice, or from elevated and dislocated lakes formed by subterranean upheavals or depressions.

The most destructive of the eruptions of Mayon was that of

February 1, 1814. It began at eight A. M., and was preceded by frequent earthquake shocks on the evening and morning before. There was suddenly shot out a column of stones, sand and ashes to a great height, obscuring the sides, down which a river of fire was seen to descend. As the darkness increased the people fled to the highest points; the glowing stones fell so thickly that there was no safety in the burning houses, and Daraga was turned to ashes. This was followed by a shower of sand until after noon. Where the day before had been cultivated fields was now only a barren waste of sand and stones to a depth of twenty to thirty feet. In some villages the cocoa palms were buried nearly to their tips, while in others the layer was scarcely a foot thick; the top of the mountain appeared to have lost over one hundred feet of its height.

In the narrative of the "Wilkes Exploring Expedition," Isarog, an extinct volcano in another province, seems to have been confounded with Mayon.

Earthquakes are comparatively rare at Albay, though Sorsogon was almost destroyed in 1840, and the houses are not built, as in Manila, to withstand their shocks. Submarine disturbances are common. In 1865 Malinao and Tabaco were inundated by a tidal wave.

I was informed by a gentleman of Albay that, in 1853, he ascended to or near the crater, and that the task was not difficult for a vigorous and expert climber. Whether he attained the summit or not is, of course, uncertain, but I fancy that the condition of the mountain is a far more important element for success than the strength of the man; human valor and endurance cannot prevail against lava currents, showers of burning cinders, and suffocating gases.

A correspondent of "Nature," July 22, 1886, writes of Mayon, then in eruption: "I tried the ascent, and climbed to about five thousand feet, when incandescent stones and ashes obliged me to come quickly down. I crossed a patch of forest half-burnt, and covered with ashes; the sight was magnificent; I never saw anything like it as a sublime scene of devastation: ashes and stones and smoke everywhere, and fearful noise like heavy artillery all around."

One of our fellow passengers, an Italian, had come from Thibet, expressely to ascend Mayon. He was a professed mountain climber, and had explored the summits of Mauna Loa, Tongaria in New Zealand, Mt. Etna, Mt. Blanc, Vesuvius, the mountains of Mexico, Central America, and California. He had made the ascent of Fujiyama in winter, and had just returned from Mt. Everest in the Himalayas, which he had explored to a height of over twenty thousand feet. When, therefore, I say that this daring, self-reliant, and expert mountaineer was forced to give up Mayon as insurmountable, some idea may be formed of the difficulty, if not the impossibility of the undertaking, and a reasonable suspicion may be entertained that no one has ever as yet actually stood upon the edge of its summit crater.

One afternoon in December, 1881, we started in a carriage from Tabaco, for Tibi or Tiouy, to visit the warm springs or geysers. The road was as bad as lava blocks, tenacious mud and holes could make it; the streams, all of which can be forded in a vehicle, show, by the color of the stones in their beds, that the water is impregnated with iron. We reached Tibi in an hour and a quarter. Here we again met our Italian mountaineer, who, satisfied that he could not ascend Mayon in its present

condition, consoled himself by taking the sulphur baths, for which the place is famous.

After a walk of a mile, over a muddy and slippery path, we came to the spring, bubbling from a cauldron surrounded by stones so hot that we could not cross without making a long detour. By the side of the hot sulphurous water flows a mountain rivulet, clear and cold. Both waters are conducted into a rude hut, where, stretched on a bamboo frame, the tourist may lie in the bottom of the running stream, the admixture of the hot and cold water being regulated at the will of the bather. The baths are considered very efficacious in rheumatic and cutaneous affections. The whole region is the bed of a river, and the surface is covered for several acres with rounded, water-worn bowlders of various sizes, among which in places bubble up the sulphurous jets; the earth on the sides is a greasy-feeling, many-colored clay, the result of decomposition and deposition by the acid waters, which the natives use for washing purposes.

About a mile from these baths, in the village of Naga, are the "manantiales" or geysers of Luzon. These are similar to the geysers of Iceland, though none of them now are "spouters." After slipping about on the unctuous mud, wading through hot silicious puddles, and jumping from one smooth rock to another, I finally, alone, came to an open space some five hundred feet in diameter, in whose nearly level surface were several holes, from three to eight inches across. From these steam was issuing, in which, at no great depth, could be heard the sizzling of boiling water. As in Iceland, the ground is honey-combed, and one fears to tread heavily, lest he should be plunged into a fiery cauldron. I had no guide, as the natives from superstitious

fears avoid these places, and I did not therefore dare to explore the uncanny spots as thoroughly as I wished.

The principal activity was at what is called the "white cone." This is a mound of moderate elevation, and is the top of a closed geyser, though an active source of heat. Columns of steam are constantly rising from it, and from the base of the stalagmitic silicious mass issue several small streams of hissing hot water, incrusting everything about them with silicate of lime, and flowing away in all directions in minute, irregular, and gradually diminishing volume. The "red cone," though now extinct, was a spouting geyser thirty years ago. It is to-day only an emitter of steam, and receives its name from its color. It projects about fifteen feet above the rim of its basin, and is a very symmetrical and beautiful object. As it is dangerous in its ever-changing surroundings, I could not attain the edge of its cavity. Between the cones is a basin, like the "pool" in Iceland, with white incrusted bank. The water is boiling hot, and is of such clearness that the sides — attached sticks, or whatever has fallen or been thrown in — can be seen many fathoms deep; it is exquisitely beautiful, peaceful, fascinating, and fairy-like.

The spouting action has long since ceased. The red cone is a dead geyser, the white is a dying one; but in their life they made, and in their death they preserve, silicious and apparently indestructible forms of great variety, shape and size, paralleled in Iceland, and surpassed only by those of the Yellowstone Park and New Zealand. Cones, cylinders, pyramids, mounds, in layers of every color and thickness, alternate with trickling streams, bubbling pot-holes, and quiet basins, with a fringe of gorgeous clays and a border of verdant hills. Here and there

are circular ridges, three to four inches high, and from one to four feet in diameter. These are of white silicious material, with level, but irregular bottoms; the skeleton mouths of former living geysers; while other funereal monuments of the dead springs are the laminated white mounds and stalagmites. One of the most characteristic accompaniments of these phenomena is the faithfulness with which the most delicate objects, such as the nervures and lines of leaves, are copied by the wonderful galvanoplasty of the waters.

As explanatory of these geysers, I was glad to find that, though five miles from the sea, and only a few feet above its level, they were very near a mountain stream. The volcanic products are acted on by acid vapors; oxide of iron and the alkalies unite with sulphuric, chlorohydric, and carbonic acids, forming compounds which are carried away by the rains; leaving the silica, silicate of alumina, and sulphate of lime, as incrustations in white powdery masses and colored clays. All of these are seen within a radius of half a mile, in this valley. Here, as elsewhere, the motive power is imprisoned steam; the water is derived from the stream in the valley, the heat from the contraction of the shrinking nucleus. The surrounding mountains supply the necessary crushing force, the water is at hand, and the Philippines are situated over a volcanic fissure.

This fissure extends from the Kurile Islands to Java, Australia and New Zealand, in a line of fracture, or at least of weakness, embracing more than one hundred and twenty degrees of latitude, and nearly the same longitude. Once established over a line of fissure or weakness, from the movement of immensely thick sedimentary deposits, the underlying floor of rock would be so modified by the heat as to perpetuate the phenomena in

that place. In other words, the wrinkling and subsidence due to the contracting nucleus would coincide with the line of greatest sedimentation. This would cause a permanent channel of least resistance, along which the volcano, earthquake, geysers and mineral springs would, perhaps for centuries, occur, or would recur, until the subterranean energy had died out.

As a general rule a volcano, like the geyser, builds itself up by its own erupted materials into a high mountain. When it attains a height to which the interior forces can no longer project its lavas, it becomes a smoker, and either bursts out lower down, or dies away with the decadence of the heated action. Mud volcanoes, like those of Java, or the remarkable one of 1868, at Kapapala, Hawaii, previously described, are intermediate between the geyser and the lava-ejecting volcano. Mayon was again in eruption, without earthquakes, during 1887.

CHAPTER IX.

JAPAN, JAVA AND NEW ZEALAND.

Fujiyama. — Geysers and mineral springs. — Symmetry and sacred character. — Its ascent for the first time in winter. — A perilous undertaking. — Krakatoa, Java. — Greatest eruption of modern times. — New Zealand. — Destruction of the famous geysers, and the pink and white terraces. — Earthquakes precede the volcanic disturbances.

THE Japanese Islands are volcanic, and are very often shaken by earthquakes. Their volcanoes, both from the difficulty of access, and the restrictions placed upon foreigners, are not well known. The great volcano of Fujiyama, however, is familiar alike in its outline and its principal characteristics to travellers and fanciers of Japanese art.

Wishing to obtain a near view of Fujiyama [or Fujisan,] and not being able to ascend it in October, on account of the snow on its sides and summit, we first went by way of jinrikisha and kango to Myanoshita, which, on account of its springs and mineral waters, is the Saratoga of Japan. In the afternoon of an October day we strolled a few miles among the mountains to the Ko-gigoko (or "little hell"). This name and other similar ones show that the place of torment has terrified the simple people of Japan for many centuries.

Ko-gigoko is simply a boiling spring of sulphurous water, emitting fumes and steam, and bordered by yellowish incrustations. It presents an uncanny scene amid the pretty surrounding hills.

We next proceeded to Hakone and its Swiss-like lake, passing on the way Ashinoyu, whose noted sulphur baths a few people were enjoying. We went by the great Tokaido road, lined and shaded by magnificent cedars (*cryptomeria*). We had here for an hour a grand view of Fujiyama, white with snow, its great peak hidden by clouds, as is usual in the afternoon.

Nothing can be more majestic than this volcano, extinct though it be, rising from the plain to the height of over twelve thousand feet, truncated at the top, and with its peak almost always snow-covered. Its ascent is not difficult to an expert climber, and has frequently been made. From its summit is unfolded a panorama beyond the power of words to describe, and probably the most remarkable on the globe. Mountains, valleys, lakes, forests, and the villages of thirteen counties, may be seen. The crater is volcanic, and the top is brownish lava. There is abundant evidence throughout the islands of volcanic action, and geysers, hot springs, active craters and frequent earthquakes indicate that the subterranean forces are still very active. As we gazed upon its beautifully curved cone, visible even from Yokohama and a hundred miles at sea, we did not wonder that it should be regarded as a holy mountain, and that it should form a conspicuous object in every Japanese work of art; it is to the natives as Mt. Blanc is to Europeans, the "monarch of mountains."

In summer pilgrimages are made around the base of the summit, and there are a number of Buddhist temples and shrines, made of blocks of stone, for devotion, shelter and storing food for the pilgrims. Fujiyama became extinct in 1708.

Hakone Lake is three thousand feet above the sea, and probably lies in the crater of an extinct volcano. Its waters are very

deep; it is several miles long and wide, and is surrounded by high hills which abound in fine scenery, solfataras and mineral springs. We crossed the lake, went part way up Atami-Tonga, whence is the best and the nearest view of the volcano, and then visited the most famous of the geysers, called O-gigoko (Big Hell).

At this place the mountains seemed to be smouldering, as sulphur fumes and steam were issuing at many points, and the ground was covered with a friable white alkaline substance. In many a hollow the water was bubbling, with clouds of vapor and sulphureted hydrogen; the soil was hot, and evidently underlaid by active fires. It was not safe to go very near, as the crust was thin and crumbling. The water running down the hills had a refreshing sound and a tempting clearness, but the thirsty tongue at once detected it to be a very strong solution of alum. The whole aspect of the place was infernal, and naturally suggested its name. While we were there an Englishman ventured too far from the beaten track, broke through the crust, and severely scalded both his feet. Had he been alone he would undoubtedly have perished. It is difficult to get a firm foot-hold, on account of the greasy, slippery character of the clayey paths, and these, with the rolling stones of the steep declivities, make the descent very fatiguing, and at times positively dangerous.

Fujiyama is almost a perfect cone, with a truncated top in which is the crater. It is, however, less steep than Mayon. Its upper part is comparatively steep, even to thirty-five degrees, but below this portion the inclination gradually lessens, till its elegant outlines are lost in the plain from which it rises. The curves of the sides depend partly on the nature, size and shape

of the ejected materials, the fine uniform ones remaining on comparatively steep slopes, while the larger and rounder come to rest farther down, and on the inclination that afterward becomes curved from the subsidence of the central mass.

It is in place here to detail an exploit of our Italian fellow traveller, which I took from his own mouth, and which has never before appeared in print. This was his ascent of Fuji-yama in winter — the only time that this feat has been accomplished, or even attempted. It took place in November, 1877. He took the usual route by Hakone and Atami. Ordinarily he travels alone, but here he was compelled to take two guides, one of whom had charge of the station nearest the top. During certain seasons of the year the people make pilgrimages around the base of the summit cone, and occasionally to the rude Buddhist temple at the highest point, constructed of rude blocks of lava. When he reached the snow line he found that his guides intended to deceive him, and to take him in a circle around the snow. Accordingly, early in the morning he aroused them, and stated his purpose to go up the mountain; they were unwilling to attempt this, but finally consented, with the intention of leading him astray. The station-keeper, too, did not wish to lose the gain, if he went over the top and down on the other side as he proposed to do. So my Italian friend went on alone, thinking his guides might follow, as he had spiked shoes and two strong iron-shod staffs, for ice climbing.

It had snowed heavily during the night, and it was very cold. The guides, seeing their patron several hundred feet above the snow line, could not respond to his beckonings, as they had no ice-shoes. They had with them all his provisions and his wraps, but in no wise daunted, as he was accustomed to such desertions,

and perfectly self-reliant, he kept on alone up the very steep incline. The snow had now changed to ice; climbing was very difficult, and a loss of foot-hold would have been fatal. Toward night he reached the summit, cold, hungry and exhausted; as a strong wind was blowing he entered the temple for shelter, and ate of the cooked rice left on the altar; there was also a small quantity of uncooked rice. He found some barrels of various sizes, placed there for containing the rice and other food of summer pilgrims. Into one of these he crawled, and managed to draw another one over it, and in that way, without any extra clothing, passed a miserable night.

The next day and night he spent in the crater, to get shelter from the wind, which swept away the stones on the top with the violence of a typhoon. His food consisted wholly of raw rice. The next day the gale abated, but now his rice was gone, and it became necessary to descend at all hazards. He began his descent of the cone by thrusting his two staffs, one after the other, firmly into the ice, and then planting his foot against them. After a short progress in this slow way, one staff broke in two, and he saw the fragments rolling over and over down the icy precipice, emblematic, he thought, of his own fate. Supported by one staff he looked around, and espied near him a flat piece of lava projecting from the ice. Carefully working his way to this, he sat down to rest; but he soon became chilled, and knew that he must start again or perish from cold.

As he was about to move he detected his guides far below, making signs for him to come on. They had probably seen the falling pieces of his staff, and were thus directed to him. They gradually drew within hailing distance, but, on account of the ice, they could not reach him to give him food and assist-

ance. At last, with the energy and strength of despair, he stood erect upon the rock, and began to descend, fearlessly, almost carelessly, and soon, without accident, stood by their side. After taking food, and being thoroughly rubbed, fastening himself between them, he managed to reach a place of safety.

He had been lost in the Sierra Nevada; he had been almost drowned in a rocky cavern in the mountains of the Hawaiian Islands; he had run for his life from the infuriated Maoris after his ascent of their sacred and forbidden mountain of Tongaria in New Zealand; he had experienced the dangers of the jungles of the Fijis, and the wilds of Australia, but never, before or since, so he declared, had he come so near to ending his eventful life, as on the ice-clad peak of Fujiyama. Though suffering from rheumatism, from his varied hardships and exposure, he had made a journey of many thousand miles to try his strength on the fiery cone of Mayon. In this, as has been stated, he was doomed to disappointment.

The island of Java is highly volcanic, and is situated over the great fissure in the earth's crust, on which Japan, the Philippines and New Zealand are also located. A chain of mountains runs along the centre, some of whose peaks are over twelve thousand feet high, and among them are forty volcanoes, about half of which are always active.

In one of these, the Tenger, eight thousand feet high, the crater, which is one thousand feet below the summit, is second in size only to Kilauea. In the south range of the Kandang, Papandayang threw out in 1772, in one night, ashes and scoriæ fifty feet thick over an area of twenty square miles, overwhelming many villages, with much loss of life. In 1822 Galungong,

a few miles distant, destroyed everything in an area of sixty miles.

One of the most disastrous eruptions on record began on the island of Krakatoa, in the Strait of Sunda, twenty-five miles west of Batavia, on the night of August 25, 1883. This island is nearly in the middle of the north part of the passage between Java and Sumatra; an important commercial highway seventy miles long and sixty to one hundred and thirty wide. The island itself was about seven miles by five. Among the many eruptions of Krakatoa, this of 1883 is by far the worst. It was, in fact, unparalleled in the history of modern catastrophes. Beginning on the twenty-fifth of August, in Krakatoa, it had on the twenty-sixth overwhelmed Anjer and other places by an immense wave, extending far along the coast. It does not appear that the Javan craters took on any extraordinary activity.

It is impossible to separate, in this case, the destruction from the volcano and the earthquake, for both were of terrific and simultaneous force, and the loss of human life has been estimated at one hundred thousand. Krakatoa was practically rent in pieces, and its northern part disappeared beneath the water, while sixteen new craters apparently rose in its place. It altered the whole physical geography of the region, and so changed the rocks, shoals, and coasts, and the contour of the ocean's bottom, that new charts of soundings are necessary for safe navigation. In the issue of "Nature" for July 17, 1884, it is stated that the explosions were heard at a distance of two hundred miles.

At first there was apparently ejected a whitish acid, and sulphurous mud, with no accompanying lava. Explosions followed

each other in rapid succession, accompanied by showers of cinders and huge fragments of rock, which were hurled high in air, and scattered far and wide. Enormous waves rushed upon the shores, causing much destruction of life and property. It increased in violence all day of the twenty-sixth, and at night was at its height. Such masses of ashes and fine dust were sent into the upper atmosphere, that to the latter were attributed by many physicists the remarkable sun glows at night and morning all over the world.

The outburst gradually calmed down on the twenty-eighth, when Krakatoa was seen to be destroyed in its northern portion. The new volcanoes said to have arisen in its neighborhood were simply huge masses of hot rock and pumice, emitting steam from the contact of the water. The lost peaks are to be found at the bottom of the sea, principally a few miles to the north. The navigation in the Straits was far less interfered with than was expected. There is no doubt that lava was formed, but none appeared; for such was the force of the explosions that every thing was blown out of the crater in larger or smaller pieces, and pumice; but mostly in a fine powder. Immense volumes of heated gases, some of them inflammable, were also discharged.

The volcano had been moderately active for at least three months before the great outburst. There had been many eruptions of mud and stones, some of the latter rounded by the volcanic friction; a phenomenon common in Java. There can be little doubt that the exciting cause was a subsidence in the Straits, letting in the water to the highly heated strata in the neighborhood of the volcanic fissure which there exists, and the consequent sudden disengagement of superheated steam.

Active volcanoes are now found only in the north island of the New Zealand group, where Tongaria attains a height of six thousand five hundred feet, and Egmont eight thousand two hundred and seventy. The latter is a perfect cone, and is always topped with snow. There are many others, singly and in chains. There are also great numbers of mud volcanoes, hot springs and geysers. It is for the last that the island is the best known. Their waters are at or near the boiling point, and contain as much silica as do those in Iceland and elsewhere.

The water of Lake Rotomahana, in the region of Tarawera, covering some one hundred and twenty acres, was surrounded by springs and fissures, which gave out steam, sulphurous gases, mud ejections, etc. In a rock at the northern end, about eighty feet high, was a crater-like excavation, open towards the lake, eighty by sixty feet, filled with a clear water which, from its white enamelled sides, had a blue tint; this was always in a state of ebullition. The silicious incrustations left by the overflow had made a series of terraces, two to six feet high, seemingly hewn from white or pink marble, each of the basins containing a similar azure water. These terraces covered an area of about three acres, and looked like a series of cataracts changed into stone, each edge being fringed with a festoon of delicate stalactites. The water contains about eighty-five per cent of silica, with one to two per cent of iron, alumina, and a little alkali.

On June 9, 1886, a great volcanic disturbance began in the Auckland Lake region by a tremendous earthquake, followed during the night by many others. At seven the next morning a lead-colored cloud of pumice sand, advancing from the south, burst, and discharged showers of fine dust. The range of Mt.

Tarawera seemed to be in full volcanic activity, including some craters supposed to be extinct, and embracing an area of one hundred and twenty miles by twenty. The showers of dust were so thick as to turn day into night for nearly two days. Some lives were lost, and several villages destroyed, being covered ten feet deep with ashes, dust and a clayey mud. The volcanic phenomena were of the most violent character, and the whole island appears to have been more or less convulsed. Mt. Tarawera is said to be five hundred feet higher than before the eruption; glowing masses were thrown up into the air, and tongues of fiery hue, gases or illuminated vapors, five hundred feet wide, towered up one thousand feet high. The mountain was two thousand seven hundred feet in height.

This eruption presented a spectacle of rarely-equalled grandeur. To travellers and strangers the greatest resultant loss will be the destruction of those world-renowned curiosities; the white and pink terraces, in the vicinity of Lake Rotomahana and the region of the famous geysers. The natives have a superstition that the eruption of the extinct Tarawera is caused by the profanation of foreign footsteps. It is to them a sacred place, and its crater a repository for their dead. It was in this part that the first earthquake occurred. One side of the mountain fell in, and then began the eruption. The basin of the lake was broken up, and disappeared, but again reappeared as a boiling mud cauldron; craters burst out in various places, and the beautiful white terrace was no more. After the first day the violence gradually diminished, and in a week had ceased. Very possibly another lake will be formed, and in time other terraces; but it is hardly within the range of probability that the beauty of the lost terraces will ever be paralleled.

In this eruption, as usual, we find the earthquake preceding the volcanic outburst. New Zealand, like the Philippines, Java and the Hawaiian Islands, is situated over a great earth-fissure or line of weakness. Subsidence or dislocation from tensile strain of the crust took place, and the influx of water to new sources of heated strata developed the explosive force. The earthquake and the volcano worked together here, as they frequently do, unfortunately in this case destroying one of the most beautiful scenes on the surface of our globe.

Mr. Geikie, in an article in "Nature" for August 5, 1886, likens this to the great eruption of Vesuvius in A. D. 79, which destroyed Herculaneum and Pompeii. In both instances a mountain which was not recognized as an active volcano suddenly burst out with terrific violence, filling the air with ashes, stones, scoriæ and mud. At each locality there were the premonitory earthquakes, the thick dark cloud of volcanic origin hanging over the mountain, the descent of dust, sand and hot stones, the discharge of mud, with, so far as known, no lava streams, and the overwhelming of an inhabited district under a deep covering of loose volcanic materials. Full accounts of the catastrophe, and the structure and breaking up of the terraces, may be found in the same journal for July, 1886.

We note, therefore, similar phenomena in the Hawaiian and Philippine Islands, Iceland, Java, New Zealand and the Mediterranean basin. We may now properly inquire what is the cause and nature of volcanic action, and what is its relation to the earthquake.

CHAPTER X.

NATURE AND CAUSE OF VOLCANIC ACTION.

Four principal theories. — Secular cooling of the globe. — Consequent stress from contraction. — Mountain chains and dislocations. — Mallet's theory of a cooling, shrinking crust on a hot centre. — Transformation of motion into heat. — Lines of weakness. — Occluded gases. — Agency of steam. — Linear arrangement of volcanoes. — Number of volcanoes on the globe. — Production of fissures. — Barometric changes. — The potentially liquid condition. — Conclusions.

THE scope of this work will not permit any detailed statement of those various theories of the causes of volcanoes which have now lost the confidence of geologists.

The four principal ones, now adhered to or opposed by leading scientists, are: —

I. That the earth's crust is very thin, and that its fiery centre is discharged through volcanoes communicating therewith. Very few geologists now hold to this belief. Since the researches of Sir William Thompson, it has been generally accepted among scientific men that the earth as a whole is more rigid than glass, and probably as rigid as steel; the centre may be hot, but not fluid, and volcanic phenomena can not be explained thereby.

It may be said, however, that Prof. Newberry, of New York, has recently published his dissent from the dictum of Sir William Thompson, maintaining that his conclusions are based on insufficient data, and opposed to some of the first principles of geological science.

II. The theory of chemical action, advocated by Sir Humphry Davy, and explained by the oxidation of inflammable materials in contact with water, has now no champions. Chemical action in most cases would absorb, rather than disengage heat, and it is most likely that the chemical energies of such substances were almost wholly exhausted before the consolidation of the earth's surface.

III. Isolated lakes of molten matter within the crust can hardly be supposed, without admitting central fluidity (even a fiery Mediterranean in a shell one hundred miles thick), nor can their maintenance under great volcanic centres be explained.

IV. Before explaining Vose and Mallet's theory, which maintains that the earth, if not quite solid at the centre, is so nearly so that all igneous phenomena may have their origin within its crust, it may be well to state the views of Constant Prevost and Joseph LeConte on the formation of the great features of its surface.

The fundamental statement made by these thinkers is that the crust of our globe is cooling at a different rate from the deeper seated portions; that the strata with the best conductive power would be first cooled and form the ocean bottoms, while those of slower conductivity would form, from the accident of their composition, the continents. At the present time the surface being comparatively cool, and the interior cooling and contracting more rapidly, there is a tremendous horizontal pressure or stress in the crust, which must yield somewhere, and this yielding is generally marked by the lines of the mountain chains. There is, also, a crushing together horizontally, with foldings of the strata, like plastic materials, and a thickening of the whole up-swelled mass. This crushing, with dislocation upward or

downward, is, from the secular contraction of the interior of the earth, constantly going on, on an immense scale. A sudden disruption may cause an earthquake, and the volcanic outburst.

Mallet's theory, now generally accepted, is, that in cooling from a nebulous mass the crust of the earth has shrunk upon the centre, and this all the more readily according to its thinness. The most of this shrinking has, therefore, gone on in former geological ages. This shrinking, crushing, dislocation, and subsidence of strata of very great extent and thickness, by the friction of motion develop such an amount of heat as to melt rocks and the sedimentary deposits between the crust and the nucleus, and these, by the agency of steam from admitted waters, are brought to the surface in the form of lavas and other volcanic products. The action of the heat is probably aided by that of highly heated and alkaline waters, which soften and liquefy the most refractory rocks.

According to Prof. T. Sterry Hunt, this transformation of motion into heat occurs in the fluid sedimentary deposits, at various depths, between the cooling crust and the hot but solid nucleus. This heat would not only soften and chemically change the lower part of these sediments, but the underlying floor of the older crystalline rocks; thus establishing a line of weakness, or of least resistance, in the crust coincident with that of the great accumulations of sediment. From this it would result that the wrinkling, or corrugation due to a contracting nucleus, would be determined along the lines of great sedimentation.

This shrinking and falling in of strata originally took place along great lines of fracture such as now mark the steep sides of an existing continent (the west coast of America, for ex-

ample); or in the direction of a sunken one, as in those of the Atlantic and Pacific. This latter is by many supposed to be indicated by a chain of volcanic islands from Jan Meyen to Teneriffe and St. Helena. Volcanic disturbances and cooling contractions and subsidence have been, I believe, the chief agents in producing the beds of the oceans and the connecting Mediterranean, Caribbean, Red, and Black seas; in the straits of Magellan, Gibraltar, Malacca, Sunda, Florida, Behring, Torres, Bass, and Cook; in the British, St. George's, and Mozambique channels; in the great lakes, like the Caspian, the Dead Sea, Superior and its connections; in the smaller lakes, the world over, and the great water courses; in the bay of Naples, the harbors of Panama, San Francisco, Rio Janeiro, Acapulco, and many others. That similar causes have produced both the elevations and depressions on the earth's surface, may also be inferred from the fact that the height of the loftiest mountains and the depth of the deepest ocean are about alike.

Certain liquids and solids have a remarkable power of absorbing many times their volume of gases, called "occluded," which may be given off explosively, on a relief of pressure from any cause; such a cause, for instance, as condensation, without chemical action. This may explain many phenomena of volcanic action, and may be excited to activity by subsidence.

The presence of water at great depths in the earth will be easily understood, when we remember that water containing gases in solution is constantly finding its way deeply into the crust. As three fourths of the globe is covered by the sea, whose average depth is two miles, and exerting a pressure of two to three tons to the square inch of ocean bottom, large

quantities must find their way down, forming reservoirs, or undergoing absorption by heated materials. This is a prolific source of the steam which is the active agent in volcanoes. As would be expected from subsidence depending on this immense water pressure, we find twice as many volcanoes in oceanic islands and near continental borders, as in the midst of the central land masses. The great linear bands of oceanic volcanoes, one ten thousand miles long, and another eight thousand, with respectively one hundred and fifty and more than one hundred active vents, could only have been formed along a long fissure from subsidence or shrinkage by refrigeration and pressure along these lines of weakness. Explosive action of a power to produce this would have torn our planet to pieces, and must have been secondary; a consequence and not a cause of fissure.

The thought naturally arises whether a planet once existing between Mars and Jupiter, and now represented only by fragment asteroids, may not have been broken in pieces by an explosive action of this kind.

The lines are sinuous, but continuous, in a general northerly and southerly direction. The exceptionally situated volcanoes of Central Asia and the Hawaiian Islands, find a better explanation in the subsidence caused by the pressure of the largest land mass and the deepest ocean, than in a primary explosion or uplift. The same cause would fix the position of the coast lines, to which mountain chains and volcanoes are parallel and near.

It may be interesting to note that the deep-sea soundings of the "Tuscarora" and "Challenger" show that the deepest holes in the ocean floor, four thousand to four thousand six hundred

fathoms, are in volcanic areas. In other words, they are found where the immense pressure would produce subsidence, which has occurred not only parallel to but between continents; as the West Indian between North and South America, the Mediterranean between Europe and Africa, the Red Sea between Asia and Africa, the Javan and Philippine between Asia and Australia — and, for the same reason, a pressure of land masses on weak spots in deep waters.

According to Prof. Judd, the first step towards the exhibition of volcanic action must be the production of an opening in the earth's crust. The almost universal occurrence of the heated stratum above referred to, between the crust and the centre, would explain, better than a fiery nucleus, the rise of one degree Fahrenheit for every fifty to sixty feet of descent; but this would vary according to the conducting power of the rocks and the depth of the heated stratum.

There are three hundred to three hundred and fifty great volcanoes on the globe. Including extinct ones, ancient and modern, there are about one thousand. There are tens of thousands smaller volcanoes, and millions of stufas, geysers, hot springs, fumaroles, mud ejections, and the like. These last may make up in number what they lack in individual energy, and may be quite as useful as the larger ones in relieving the imprisoned dying volcanic forces. The greatest number of the principal volcanoes (about one hundred and seventeen) in North, Central and South America, are on the continents, and twice as many in the oceanic islands. At an early geological period the whole line of the present Atlantic was probably traversed by a chain of volcanoes on the grandest scale; but at present only a few parts of this range are above

the sea, forming the isolated islands and groups now seen. From the pressure of the ocean — a ton on every square inch of bottom, for each one thousand fathoms of water — it does not seem possible that volcanic cones could be built up from the bottom of a deep sea and reach the surface; but quiet outwellings might in many cases occur from fissures in the ocean beds.

The periodical activity of volcanoes, their violent paroxysms and seasons of rest, sometimes for centuries, seem natural on the theory of subsidence and fissure, according as it is sudden and great, or slow and slight, letting in water, and thus exciting and perpetuating steam action along lines of weakness. Explosive force seems inadequate to account for them. The shifting of the axis of eruption, as in Etna, and the linear arrangement all the world over, indicate subsidence as the primary cause, and eruption as a secondary effect.

As Prof. Judd states, Mr. Scrope long ago pointed out that the ordinary argument for the explanation of volcanic outbursts is simply "reasoning in a circle." It is assumed, on the one hand, that the fissures are produced by steam and other forces set free by the passage of sea water to interior heated masses; and, on the other, that the production of these fissures leads to the influx of water. If the passage of water by the fissures produces the eruptions, what has caused the fissures? If the subterranean forces can produce the fissures, why not the eruptions also? It would seem, then, that only subsidence or fracture, as above explained, can resolve the difficulty.

Changes of two inches in barometric pressure within a brief period are not uncommon. A fall to this extent indicates the removal of a weight of about two million tons from each square

mile of the surface of the earth implicated. This relief of pressure is enough to cause the flashing into steam of the superheated water, or escape of explosive gases, which we have good reason to believe exist in volcanic areas. Such a relief of pressure, whether from terrestrial movements or atmospheric changes, may be better appreciated by an allusion to what has been called the " potentially liquid condition."

The boiling point of liquids, and the fusing point of solids, are very much raised by great pressure, so that water may remain liquid at a temperature far above two hundred and twelve degrees Fahrenheit in the depths of the earth, while masses of rock may be in a solid state at a temperature far above that at which they would melt at the surface. They are then said to be in a " potentially liquid condition." Upon the relief of this pressure, the water would flash into explosive steam, and the rock assume the liquid or lava state. This would explain how by a fissure the ejecting force and the ejected material of a volcano might arise, with or without an earthquake.

This chapter may be closed with the four following conclusions, deduced from Prof. Judd's researches and an examination of volcanic records, ancient and modern:

I. A long period of quiescence is generally followed by an eruption, either long or violent.

II. A long-continued or very violent eruption is usually followed by a prolonged period of repose.

III. Feeble and short eruptions ordinarily succeed one another at brief intervals.

IV. The violence of a great eruption is generally inversely proportional to its duration.

In a single sentence, then, it may be stated, as deduced from the history of volcanic phenomena, specimens of which have been here detailed from personal experience, that such phenomena are due to one simple cause, viz: the escape of imprisoned steam from masses of molten matters in the crust of the earth. That this is occasioned by the water from the surface of the land, or from the seas, gaining access to the sedimentary strata between the crust and the centre, and becoming heated by the crushing movements, uplifts, depressions, and fractures, consequent on the secular cooling of our globe. And that this occurs whether we consider an eruption of the majestic Etna or the humblest bubbling hot spring. The same grand law, with innumerable modifications, builds, adapts for life, and finally destroys a world.

CHAPTER XI.

EARTHQUAKES.— GENERAL CONSIDERATIONS.

Most common in volcanic regions.— May occur in non-volcanic districts. — In Asia Minor, England, Atlantic coast of Africa, New England, California, Spain, and the Mississippi Valley.— Theories.— Dr. Young in 1807.— Mallet in 1846.— A wave of elastic compression.— Velocity of transit.— Different movements.— Origin.— Marine earthquakes.

ALTHOUGH there is no necessary connection between the volcano and the earthquake, other than that both are the effects of one great cause — the secular cooling of the globe — it is true that the latter is most likely to occur in volcanic regions. Such regions are along the west coast of North and South America, Iceland, the Azores, the Mediterranean, and the Hawaiian, Philippine and Javan Archipelagoes.

They have, on the other hand, in memorable instances, occurred in districts far removed from existing or extinct volcanoes; as in the Mississippi and St. Lawrence valleys, New England, the Atlantic seaboard, Portugal and Spain, Asia Minor, and the Himalayas. In November, 1881, there were twenty-nine shocks, in seventeen out of thirty days, in different parts of Switzerland, in regions now non-volcanic.

It may be well to cite a few instances in confirmation of the fact that earthquakes are independent of volcanoes, and to show that they are generally, or at all events on land, due to that rupture of strata, upward or downward, consequent on the hori-

zontal thrusts or tangential pressures, to which Constant Prevost, in France, was among the first to draw attention.

On the third of April, 1881, the air on the island of Scio, off the coast of Asia Minor, was heavy, though the thermometer marked only sixty-eight degrees Fahrenheit. There was a southerly wind, a cloudy sky, and pale lightnings on the horizon. Suddenly, at a few minutes before two P. M., and without any previous trembling or subterranean noises, a fearful cracking was heard, and a violent shock shook the island. The ground trembled, and moved in every direction; nearly all the buildings were at once crumbled down, and thousands of persons were killed and buried in the ruins. Great fissures opened in the earth, which engulfed scores of persons at a time. Tremblings succeeded each other at irregular intervals, becoming less frequent and violent till toward night. On the eleventh of April, at seven P. M., a second shock, accompanied by a loud report, shook the ground. The whole region from Scio to Cape Mastic suffered greatly; the fields all about the city were fissured irregularly, and in some places elevations were leveled or depressed. This was evidently a local subsidence, without volcanic disturbance, in a granitic and limestone region. The tremblings continued for several days, or until the dislocated strata had settled to a state of rest.

On the twelfth of April, 1884, at 9.30 A. M., there was a severe shock in the southeast counties of England, over a line seventy miles from north to south, from the Thames to Bury St. Edmunds, and from twenty to fifty miles from the sea. It lasted but thirty seconds. The greatest violence was about midway on this line. As this region is a thousand miles from the Atlantic volcanic centre, or from any earthquake locality,

and as there was no news of a violent disturbance at a distance, the most natural explanation is that it was from a local rupture at the south and west, where, in the districts of the Malvern and Mendip Hills, the strata are very much "faulted." The limestone is rich in hot springs, whose corroding waters probably undermined the deep layers, and thus contributed to local subterranean changes, the shock of which was communicated in the direction rendered most conductive by structure and other characters; and this, whether the original movements were due to geological, physical, electric, atmospheric, or other causes.

On the tenth of August, 1884, a shock was felt along the Atlantic coast of America from Virginia to Maine, evidently from disturbance in the non-volcanic Appalachian region. It lasted about ten seconds, and did but little harm. This was probably the preparatory forerunner of the earthquake at Charleston, S. C., in 1886.

In November and December, 1884, several shocks were felt throughout Southern and Central New Hampshire. Just after midnight of November 23, one occurred, the movements lasting about sixteen seconds, waking people up, smashing crockery, and extending through Keene, Peterborough, Contoocook, Manchester and Concord. The direction was apparently northeast to southwest. Slighter shocks were felt ten days before. In Laconia, December 17, was experienced the heaviest shock ever known in that region; at Centre Harbor it lasted half a minute. The direction was from north to south. It is stated that it was preceded by a loud report, like a clap of thunder, which was followed for some seconds by a heavy rumbling sound. Similar accounts were published in various parts of

this country and Europe, in districts far removed from any volcanic centres, ancient or modern.

In December, 1885, San Francisco, often visited by the earthquake, though now far from any volcanic activity, had an experience of six seconds, which made all the old buildings creak, and all movables rattle.

From Christmas, 1884, to the early part of January, 1885, a series of earthquake shocks occurred, extending over a large part of Southern Spain, but especially destructive of life and property in Granada and Andalusia. Loud rumblings were heard, the ground was cleft, and men, animals and houses fell into the abyss. Its course was in some places from west to east, in others from south to north, according to the strata involved. The longest shock lasted fifty seconds. In some places there were three, in others, at a little distance, seventeen shocks; pointing distinctly to rupture and shock till the dislocated strata attained rest. There was, no doubt, great electrical disturbance, from the immense friction attending the depression, as was shown by the flashes of lightning from a clear sky.

There is little need of adducing any more instances, although hundreds could be given, to show that earthquakes occur, the world over, in regions not now volcanic, and in some, like rock-ribbed New England, where there are no traces of volcanic activity in the present geological epoch.

The theories brought forward to account for earthquakes are numerous and fanciful in the extreme. No satisfactory connection with atmospheric conditions has been proved, except as these are an accessory, and possible exciting cause. They occur everywhere: at all seasons of the year, at all times of day, and in all geological formations and epochs; they seem to follow no

laws of periodicity, and, in many remarkable instances, are independent of volcanoes. Attempts have been made to connect their phenomena with the solar spots, terrestrial magnetism, the phases of the moon, and the tides, but without satisfactory results.

Prof. Guyot states that there can be no doubt that within the tropics, at least, earthquakes are most common at times of greatest atmospheric disturbance, but a precise relation between the two classes of phenomena has never been established.

Mallet is of opinion, from studying the data of eighteen and one half centuries, that they are the least frequent before the autumnal equinox, while others regard the solstices and equinoxes as all-critical periods. Where the doctors so disagree, it is a great satisfaction to be able, as far as present knowledge goes, to refer the earthquake as well as the volcano, to a simple dynamic force depending on the secular cooling of the globe. The cause is the same in all, while the effects vary according to geological and wholly terrestrial circumstances.

Dr. Thomas Young, in 1807, seems to have been the first who suggested the nature of the earthquake shock, as afterward elaborated by Mallet in 1846. This theory is now generally received; viz: that the motion of the earth at any point is a vibratory one, and is propagated like a wave of sound. According to Mallet, an earthquake is the passage of a wave of elastic compression, shock or pulse, by an observer, in any direction or from any centre, in which each particle of the earth vibrates forward and backward, in nearly a straight line, in a curve more or less complicated according to superficial or deep obstructing causes. The direction may be anywhere between vertical and horizontal, through the crust or along the surface, with or

without sound and ocean waves. This vibratory movement implies a motion forward and backward, in an elliptical or other curve; the greatest destruction is usually during the forward movement, when the upward velocity is at its maximum; the downward motion accompanies the return pulse-movement, and is slower and less dangerous. These pulsations may be in curved lines, but not in circles. The throwing down of buildings and walls, he thinks, is due to the velocity of the motion of the particles in the small elliptical orbit, and not to that with which the shock passes over the earth. This velocity varies with the elasticity and density of the rocks and soils in its path. We find the phenomena of reflection, refraction, and interference, according to the strata involved, just as in the case of sound.

The velocity of transit of the wave in the Naples earthquake of 1857 M. Mallet determined as at one thousand to six hundred and fifty feet per second. In some instances a velocity more than double this has been noticed. The velocity of each particle in its small orbit is, on an average, only twelve feet per second; so that the rapidity of transit is very much greater than that of the shock which causes the destruction; Mallet estimates the amount of the shock, during that earthquake, as such as would be received by an obstacle run into by a locomotive moving ten miles an hour.

The vertical movements are much more destructive than the horizontal, and are readily distinguished; in fact the Spanish, in the Philippines, apply the word *terremoto*, earthquake, only to the former, and call the latter *temblor* or trembling.

In the "Philosophical Magazine," 1881–82, speaking of the earthquakes of Japan, Milne and Gray assert that a point on

the earth's surface may not move uniformly forward and backward during the whole of the shock, even though it emanate from one point, which is more likely to pass through a series of complicated curves, as they may be very irregular, both in magnitude and course, in the same earthquake. In fact the problem is a very complex one, and observers have called to their aid an automatic instrument of registration, the seismograph or seismometer; these vary from simple plates strewn with sand, tide gauges, barometers, and pendulums to complicated arrangements of vertical springs, mercurial tubes, and electric and magnetic apparatus, which cannot be described here; probably the most complete seismic apparatus in the world is at the Palmieri Observatory on Vesuvius.

The notions as to the origin of earthquakes have been as diverse as those concerning the nature of the shock. Explosions of gas and sulphurous compounds, electrical discharges, falling in of caverns, the flashing of water into steam, have in turn been accepted and discarded. There can be no question that the sudden expansion of steam under high pressure may often cause a local shock, but we speak here only of widely extended disturbances, which at present are generally explained on Mallet's theory.

Many, perhaps most, recorded violent earthquakes begin in the ocean bed, far from land, and where the weight of water above is greatest. These may be accompanied by huge waves destructive many thousand miles distant. The great earthquake which destroyed Lisbon in 1755 probably originated under the ocean west of Portugal.

We frequently read from the logs of mariners of severe and inexplicable commotions of the surface, producing immense

waves. The following is such an account of a brig which suffered during a marine earthquake in latitude thirty-seven degrees north and longitude seventy-five degrees, on the western edge of the Gulf Stream. It was the fifteenth of August, 1884. The sky denoted a hurricane, and the vessel was put under short sail. The wind veered to every point of the compass, and then lulled. Suddenly a roar of the sea was heard; the ocean boiled like a pot, heaping up great waves which tossed the brig about like an egg-shell; now on the crest of a sea, and now in the trough, her foreyard crossing to the water on either side; the vessel was seriously crippled. There was no wind at the time, and the seething and boiling of the water was like a cauldron. The convulsion must have had its centre four or five hundred miles east of Hatteras. Only a very small proportion of such occurrences ever come to the notice of the public or scientists; the most of them are buried in the log-books of the mercantile marine, with whom the chief object is a safe and speedy voyage, without much observation of the perturbations of the water outside of the limit of danger and loss.

CHAPTER XII.

FRACTURE, UPHEAVAL AND SUBSIDENCE.

Theory of displacements.— Fracture from stress, contraction, or subsidence.— Faults.— May and do occur everywhere.— Elevations and foldings of the crust.— Instances of subsidence after earthquakes in many parts of the world.— A volcanic vent no safeguard against an earthquake.— Earthquakes in Iceland.— Volcanic fissures in the moon.— Charleston, S. C.— Other earthquake disturbances and subsidences.— Barometric changes as causes.

GOING back to Constant Prevost's researches on the physics of the globe, and to Mallet's theory, as heretofore given, attention may be called to a comprehensive and comprehensible statement on the "Cause of Earthquakes" in the "Forum" for December, 1886, by Maj. Powell, of the United States Geological Survey. His theory is essentially that which may be called Mallet's, though many before and after him have contributed to the now generally accepted views of geologists and physicists, that earthquakes are due to displacements or fractures of the crust of our globe, sometimes with elevation, and sometimes by subsidence, and sometimes by both.

In other words, wherever and whenever, in the cooling shrinking crust of the earth fracture takes place, from stress or tangential thrust or crushing, or wherever and whenever support is taken away from overlying strata, by contraction, pressure, chemical action, emission of lavas, corroding and

heated waters, occasional local explosions, aided, no doubt, by terrestrial, meteorological, and astronomical causes, said strata are broken, with upheaval or depression. These may be hundreds of miles in extent, and leagues in thickness, and, according to the violence of the rupture, produce a shock which may be transmitted to long distances by land or beneath the water, with a force and direction depending on the elastic characters of the strata.

In old geological times, the dislocations, uplifts, and depressions of strata, called "faults," were much more common and extensive than now; but, as the tension and pressure which formed the immense ancient foldings have in some measure been modified by the increased thickness of the crust, it seems natural that depression should be more marked than upheaval. The Jeddo [Japan] earthquake, in 1881, according to Mr. Milne (Report of British Association, at York, 1881), originated in a region which is very much faulted, with evidence of recent elevation. In countries where the strata have not been disturbed since their original horizontal deposition, as in many parts of Northern Europe, there is comparatively little opportunity for violent upheaval or subsidence; still the world-wide and enormous pressures, consequent on secular refrigeration and contraction, are constantly, though slowly, acting, folding very extended formations, with depression here and elevation there, till finally rupture must take place to restore the equilibrium in the depths. These results are occurring in all lands, and, if in any degree sudden or violent, constitute an earthquake.

Major Powell gives considerable space to fractures or faults, with elevation or subsidence, which he speaks of as ranging

from a few feet to ten thousand feet in height, and from less than one mile to one thousand miles long. These displacements of strata deform or change the contour of the surface constantly in the past and the present, and certainly in the future. He places more stress on the elevations, and among others he cites Owen's Valley in 1872, of whose earthquake he finds a satisfactory explanation in a fault forty miles long, and five to twenty-five feet high. In this case there was probably both upheaval and depression. In Concepcion, 1835, there was four to five feet elevation, afterward settling to two. In the Sierra Nevada, on a line five hundred miles long, and fifty to seventy wide, there has been an uplift on the east side of twenty thousand feet, in a very irregular way, by hundreds of thousands of small displacements; "a record, to those who can read geological evidence, of thousands, or rather millions of earthquakes."

The same may be said of the faults and foldings of the Appalachians, with probably hundreds of thousands of earthquakes, of which the one at Charleston, S. C., in August, 1886, was a noted example. Man has catalogued thousands of such convulsions, but he might as well try to make a list of rain falls; what can come under his notice are utterly insignificant in point of numbers.

The evidences of subsidence after earthquakes are more numerous and striking than those of upheaval, especially in volcanic regions. This would be expected when we remember the amount of material taken from the interior of the crust, leaving cavities behind, which acts as a depressor by its accumulated weight. The eruption of Vesuvius in 1794 yielded forty-six million cubic feet of lava; that of Etna, in 1669, twice as much,

and that of Skaptar Jokul, in Iceland, in two years, twenty-one cubic miles.

In the earthquake which destroyed Lisbon, in November, 1755, in which sixty thousand people perished, a part of the city was permanently engulfed in the bay to a depth of six hundred feet; the shock was felt over an area six times that of France. To imagine this the result of the action of explosive gases or steam seems out of the question, for such violence would have torn Southern Europe to tatters.

Port Royal, Jamaica, sunk beneath the sea in June, 1692. Near the mouth of the Indus, in 1829, two thousand square miles sunk. In 1779, Papandayang, one of the largest of the Javan volcanoes, fell in, and similar subsidences have since occurred.

In August, 1883, the island of Krakatoa in great part disappeared. Tjeringen, with a population of ten thousand, and several other coast towns, entirely disappeared, buried beneath the waters. On the day after this outburst, the sea fell fifteen feet at Colombo, Ceylon, two thousand miles distant. In the catastrophe in Anatolia, October, 1883, many houses and people were swallowed by rents in the ground.

In Book II. of Lyell's Principles of Geology, are given many instances of volcanic subsidence; among them are the following: In Quito, July, 1698, according to Humboldt, a great part of the crater and summit of the volcano Carguairazo fell in. Lyell says: "M. Boussingault declares his belief that if a full register had been kept of all the convulsions experienced here [Quito] and in other populous districts of the Andes, it would be found that the trembling of the earth had been incessant. The frequency of the movement, he thinks, is not due to

volcanic explosions, but to the continual falling in of masses of rock, which have been fractured and upheaved in a solid form at a comparatively recent epoch."

Other illustrations of subsidence are adduced in chapters twenty-eight to thirty-three of Lyell's "Principles." In St. Domingo, November, 1751, Port au Prince, and a part of the coast sixty miles long, sunk, and has ever since been a bay. In 1762, in Hindostan, sixty square miles of the Chittagong coast suddenly and permanently disappeared, and a mountain was also no longer to be seen.

In 1783, in Calabria began a series of shocks, extending over four years, in a region where there are no volcanic rocks; in Messina, Sicily, on the opposite side of the narrow straits, the shore was rent, the quay sank fourteen inches below the level of the water, the soil along the port inclined toward the sea, and houses were much fissured. There were long rents in Soriano, six to ten and one half feet deep, and many fissures in Polistena; some very long and deep. In Terranuova, houses were uplifted or sank. Most of these chasms and fissures ran parallel to some pre-existing neighboring gorge; some took various directions, like cracks in a broken pane of glass. In the vicinity of Oppido houses and stores were swallowed up, the sides of the chasms sometimes suddenly closing; one chasm was five hundred feet long and two hundred deep. The rents did not occur in the more solid rocks, and in clayey strata sometimes were very short. No eruption occurred from either Etna or Stromboli during this Calabrian earthquake.

In Sicily, near Terranuova, in 1790, the ground sank for a circuit of three Italian miles, in one place thirty feet, during seven shocks, probably connected with Etna. In 1790, accord-

ing to Humboldt, at Caraccas, a granitic soil covered with forest sank, leaving a lake eight hundred yards in diameter, and between two hundred and three hundred feet deep. In 1786, according to Horsfield, shocks were felt near Batur at intervals for four months, followed by an eruption; rents were formed, tracts disappeared, and villages were swallowed up. In 1772 Papandayang lost four thousand feet of its height, and an extent of ground on and around it, fifteen by six miles, was engulfed. Other great subsidences are given in the "Philosophical Transactions" for 1693–94.

The phenomena attending the volcanic eruption of Mount Saint Augustine, Alaska, October 6, 1883, seem to confirm the theory of subsidence. A vertical rupture extended across it from east to west, the northern slope having sunk away to the level of the northern cliff. The cleft was wide enough for a vessel to sail through, had there been sufficient depth of water. The eruption was accompanied by a wave, twenty-five to thirty feet high, and others of eighteen to fifteen at intervals of about five minutes.

At Krakatoa, Java, where once was its northern portion, bottom was not found at a depth of twelve hundred feet. The immense pressures of the depths of the earth and the superincumbent ocean, may explain the opening of a fissure along the Javan line of weakness, and may also account for the consequent admission of water, and the escape of superheated steam. In the order of sequence, therefore, came, first, fracture and subsidence along the fissure in an already weakened volcanic area, then the earthquake accompaniment, and then the volcanic outburst.

In Nicaragua a great eruption of Momotombo occurred on

the twenty-second of May, 1886. It was accompanied by severe earthquake shocks, during which the whole area of Managua, the capital, with ten thousand inhabitants, sank three feet, completely destroying all the most important buildings, and many lives.

A volcanic vent, therefore, is no safeguard against an earthquake, but rather a predisposing local cause, as it leads to the preparation of caverns which may be the theatre of subsidence. These may, however, in a few insignificant cases, mitigate accompanying explosive efforts. The destructive earthquakes that visited Manila in 1863 and 1880, took place in a region one hundred miles from any active volcano. They originated in a chain of mountains to the far northeast, and under a district where no volcanic disturbance has been known for centuries, but where very large cavities exist. The eruption of Vesuvius in A. D. 79, when its volcanic character had been forgotten, was preceded by a severe earthquake eleven years before. This was not a case of cause and effect.

In "Oversigt over die islandske Vulcaners Historie," by Th. Thoroddsen, Copenhagen, 1882 (pp. 170), I find the following statistics of earthquakes and their accompaniments in Iceland since the year A. D. 1000. These also are proof in support of the subsidence theory. There were fifty simple volcanic eruptions, without recorded earthquakes, in twenty different localities far removed from each other, generally small and of short duration. If accompanied by earthquakes, they were so insignificant that they are not mentioned in the above work. Many of them, toward the middle of the thirteenth century, were sub-marine. Of eruptions with recorded earthquakes, there were twenty from 1151 to 1875; in almost all of these it is stated that the

earthquake preceded the eruption, sometimes by a month. Of many severe earthquakes without recorded eruptions, there were forty-four from 1013 to 1872; that of 1732 continued for two weeks; that of 1784 for twelve days; in that of 1789 the whole plain of Thingvalla, from the chasm of the Raven to that of All-Men, then a deep depression of one hundred feet, fifty square miles in extent, was lowered about two feet (sixty centimetres); that of 1808 was felt in various parts of the island. Most of these one hundred and fourteen disturbances occurred, for reasons before stated, in the neighborhood of the great volcanic centres, especially of Hekla in the southwest, and Lake Myvatn in the northeast.

From this resumé we see that earthquakes have occurred at all seasons of the year, in every part of the island, and apparently independently of volcanoes, though sometimes accompanying them; and that they move in regions far removed from each other, at short intervals. The face of the country has been suddenly changed; crevices and depressions have appeared; the course of rivers has been altered, and great changes in the volume, locality and temperature of the geysers have been noticed. These convulsions were attended with famine, plague, much loss of farm property, and the death of at least one hundred persons. In the fifteenth century only four eruptions were recorded, while in the thirteenth and fourteenth, and sixteenth to nineteenth, they were numerous and violent.

The fact, therefore, seems undeniable, that subsidence is one of the chief features of modern earthquakes.

Fissures in the ground, the result of earthquake subsidence, are extremely common in all parts of the globe, volcanic and non-volcanic. Most extraordinary chasms, evidently the result

of subterranean causes of tremendous power, have been noticed in the moon. Some of these have been described by Prof. S. P. Langley in the Century for March, 1885. One is the so-called "Railway," an almost straight line, on one side of which the ground has abruptly sunk, leaving the undisturbed part standing like a wall, and forming "a fault," as geologists call it. "This is one of the most conspicuous examples of its kind in the moon, but it is only one of many evidences that we are looking at a world whose geological history has been not wholly unlike our own. . . . It cuts through plain and mountain for a length of sixty miles. Such cracks are counted by hundreds on the moon, where they are to be seen almost everywhere. . . . This one varies in width from an eighth of a mile to a mile; and though we can not see the bottom of it, others are known to be at least eight miles deep, and may be indefinitely deeper." In these we cannot fail to be struck with the resemblance to terrestrial subsidence earthquake phenomena.

The shocks which devastated Charleston, S. C., and the neighboring region, beginning August 31, 1886, and continuing at irregular intervals for several months, though so strange to the ordinary observer in this country, are in conformity to the theory of displacement, whether we adopt the theory of a land slide of the coastal region, or deep-seated subsidence. The latter theory seems to me the most probable, in view of the weight of the mountain range, the great area of disturbance, and the absence of any surface indications other than a few fissures. There were no volcanic phenomena observed, and the region between the Appalachian range and the Atlantic is far from any volcanic centre. It was probably several thousand feet below the surface, and over a long line of fracture.

As specimens of earthquake subsidence may be mentioned the crater of Kilauea, and its contained lake of fire; the valley of Thingvalla; Taal crater in the Philippines, and the "Val del Bove" on Etna. During the shocks at New Madrid, Mo., in 1811, which lasted many months, in a region far removed from a volcanic centre, there opened several long and deep fissures, and the site was known for a long time as the "sunk country." To these may be added the Yosemite Valley, which, I believe, is the result of a local subsidence, and not, except slightly, of glacial action.

Before the Vesuvian eruption of April, 1872, there were numerous vibrations, without upheavings. Near Puzzuoli, on the Bay of Naples, a conical hill now known as Monte Nuovo, four hundred and forty feet high, was formed in one week; from September 29 to October 5, 1538. It covered an area more than half a mile in diameter, in a space formerly occupied in part by the Lucrine Lake. For more than two years earthquakes had prevailed in this region, the greatest being on September 27 and 28, when they were almost continuous. At eight A. M. on the twenty-ninth a depression was noticed at the site of the future hill. From this water began to issue; at first cold, then tepid, then hot. As the heat increased, steam, scoriæ, pumice and sand were poured out from a fissure in the swollen ground, which built up the hill, as now seen, chiefly in two days and nights. In the centre is a vast circular depression; a crater of subsidence. The gradual increase in the heat, as evinced by the ejections, seems to indicate that it was an after product, and not the cause of the outburst. The earthquakes preceded the volcanic action.

An earthquake is not in itself a permanent elevator, though

it often accompanies volcanic outbursts. The statement has been attributed to Dolomieu and Daubrée, that an earthquake in a non-volcanic region is an effort to establish a volcano. It would be more correct to say, according to modern notions, that it is simply the shock from the fracture of strata unable to withstand the stress, and of the thrust consequent on the secular refrigeration of the crust. Much heat is certainly thus developed, but that can not fairly be called a volcanic attempt. It has been shown by Judd and others that, if a part of the earth's crust should have its temperature raised two hundred degrees Fahrenheit, its surface would be elevated one thousand to fifteen hundred feet; and it has been mentioned that Le Conte accounts, by the different rates of conduction of heat from the centre, for the great continental movements of past ages, and the existing inequalities of the earth's surface.

The liability to recurrence in the same place is to be explained by the continuance of the cause; one displacement prepares the way for a change from an unstable to a fixed equilibrium. When this is attained, there may be quiet for centuries, but it is more liable to disturbance as the geological cooling, contraction, and rupture go on, giving rise to an earthquake. The shock at Lisbon, December 21, 1883, confirms this.

On March 13, 1884, at Pocahontas, Va., there was the most remarkable and destructive coal mine explosion known in the annals of American mining. During the preceding twenty-four hours the barometer rose about thirty-five hundredths of an inch; equivalent to an increased pressure of more than two hundred and fifty thousand tons per square mile. Such a suddenly imposed weight must have compressed the coal beds, forcing out occluded gases in jets or "blowers," aided very

likely, and perhaps caused by a deep-seated dislocation of strata, or "fault," with the resulting escape of inflammable gas.

In Harper's Magazine for June, 1885, Prof. Proctor has something to say on earthquakes, which he believes may be brought about by changes of atmospheric pressure. He states that a rise in the barometer of one half an inch over a space embracing ten thousand square miles, or less than one sixth of the State of Missouri, means an increased pressure on that area of four thousand two hundred million tons. If an atmospheric wave passed over the United States, in the eastern half the barometer one half an inch lower than in the western half, and then one half an inch higher, it would be as if a mass of seven hundred thousand million tons had been shifted from west to east. Such and even greater changes take place, and must have an effect in producing subterranean disturbances. An increase in height of one inch in the mercurial barometer means six hundred and fifty pounds to each square foot, or about eight hundred and fifty-two thousand tons on a square mile. This must powerfully aid other causes, as weight of ocean on weak coast lines, and pent-up gases. The stillness and calm in the air preceding an earthquake are the result of increased atmospheric pressure or high barometer. Mr. Proctor's estimates are somewhat higher than those of other authors, but, even taking off one third, the force is a tremendous one.

From this it may be admitted that barometric changes may occasionally determine the fracture of strata about to yield and cause an earthquake of more or less intensity. In the earthquake, even in violent catastrophes, there is less laceration of the surface, though the destruction, even if superficial, is more extensive than in the local explosion of a coal mine. The

rumblings in Virginia were aërial rather than subterranean, and the duration longer. The earthquake usually does its work in less than half a minute. The Pocahontas movement was a violent, local disruption, with every accompaniment of explosion, and not the long-extending, comparatively noiseless wave of an earthquake. On the other hand, a few weeks before, in Pennsylvania, there was a sinking in of a coal mine, with no explosive violence; the effect had quite the appearance, and was accompanied by the phenomena of an earthquake on a small scale.

It may be claimed, therefore, that nearly all so-called earthquakes, of modern times, have been the result of fracture and displacement, and especially of subsidence; that only a few, insignificant and local, have been because of explosive force; and that no region can be considered as exempt from their occurrence.

CHAPTER XIII.

MANILA EARTHQUAKES.

Early records.— In 1645. — In 1863, a most destructive earthquake.— In July, 1880, a three days' disturbance.— Great destruction of life and property.— Description by an eye-witness. — Effect on man and animals.— Premonitory symptoms.— Direction of the waves, and effects on buildings.— Explanation of origin.

ON landing in Manila, not many steps can be taken in any direction without meeting evidences of the earthquakes which have visited this city and neighborhood. Ruined dwellings, shattered churches, dilapidated walls, and heaps of rubbish are everywhere visible, the most of it the work of a few seconds in 1863 and 1880. Some of the destruction, however, dates back more than a century, and is now covered with creeping and climbing vegetation.

The earlier records of these catastrophes in the Philippines are doubtless exaggerated. We read in them of mountains, though these are doubtless only hills, appearing and disappearing, of rivers swallowed up, of the formation of lakes, of eruptions of sand and ashes, and of great agitation of the sea. None of them, however, are sufficiently explicit to quote as anything more than evidences of uncommon subterranean violence, with great destruction of life and property and changes in the features of the country. Such a one was noticed by Aduarte in 1693, as having occurred in Luzon in November, 1610, extending from Manila to the extreme north of the island, the

most terrible known at that time; palm-trees were engulfed to their tops, the hills were moved bodily, and the soil waved like the ocean.

One of the most memorable happened November 30, 1645. It was graphically described by Mr. F. E. Foster, in the Japan Daily Mail of May 26, 1877. At about 8 P. M., he says, the sky was clear and the sea calm, and the whole community in repose. Suddenly the city of Manila was precipitated into ruins. The sea rose with a broad swell, and lashed the very walls. Frightful noises fell upon the ear, the earth trembled, and animals cowered to the ground in terror. Again and again were the shocks repeated; walls cracked under the unseen power which swayed them. The people in fear sought refuge under doorways and arches, but roofs and timbers fell about them, immuring many in a common grave. The cries of the wounded and dying mingled with the crash of crumbling edifices. In less time than has been consumed in the narration of the catastrophe, the destruction was complete. At daybreak the sun shone upon the ruins of the capital, not one stone of which remained upon another. The cathedral, most of the churches and public buildings, and countless private ones, were ruined.

Other severe shocks were experienced in 1699, 1796, 1825, and 1852; and on June 3, 1863, at 7.25 P. M., after a sultry day, during the vesper service of Corpus Christi, a severe earthquake, with tremblings, waves of shock, and loud subterranean rumblings, took place. The cathedral roof fell in, burying a large part of the congregation in the ruins. Many of the worshippers were killed, and hundreds wounded. In the great square the Governor-General's palace was unroofed, and his

family barely escaped with their lives. Most of the churches were rendered useless; lofty towers fell, killing many persons, whose fate was tolled on the bells by unseen hands. Almost all the public buildings were levelled, or left untenantable; nearly every private house suffered more or less damage, though, from improved methods of construction, the loss of life was less than in previous catastrophes. The shock lasted only half a minute. The ground opened in many places, giving forth gases, and the water in the river became dark and noisome. Every one who could fled to the light and elastic nipa houses of the suburbs for safety. The loss of life was estimated at four hundred, and of property at eight million dollars. There seemed to be two waves; one from south to north, and the second from east to west; and some fancied there were circular movements, but as the observations were made without instruments, and under great fear and excitement, in the time of half a minute, they cannot be looked upon as reliable.

Again, after years of quiet, and when the country was remarkably prosperous, on the eighteenth and twentieth of July, 1880, there came a series of very violent shocks, throwing the community into despair and terror, and paralyzing the progress of the province. It seems a question difficult to solve, whether the inexhaustible fertility of these islands is not, like the charms of Circe, a lure to destruction. Subject as they are to the typhoon and the earthquake, the end is almost certain to be desolation and death, and one against which neither foresight can prevail, nor strength nor precaution protect.

At 12.40 P. M., on Sunday, the eighteenth of July, the shock

A STREET OF MANILA.

began in Manila, with tremblings and complicated movements, continuing for seventy seconds. On Tuesday, the twentieth, it commenced at 3.40 P. M., lasting forty-five seconds. The second shock was more violent than the first, and completed the destruction which the first had caused. Surprise gave way to terror, and the people fled by land and river to the country. Fortunately both attacks happened in the day time, and the movements were slow, or the loss of life must have been great. The principal danger was from the downfall of the tiled roofs, which are now largely replaced by galvanized iron.

The Sunday movement came on gradually, like a long wave; but on Tuesday, after a few premonitory tremblings for an hour or two, there followed a sudden and irregular shaking, which gave no such chance of escape from the houses as did the first one. At ten P. M. on Tuesday, a third shock occurred. This was not a severe one; simply knocking furniture about, but doing no serious damage, for there was now little to destroy.

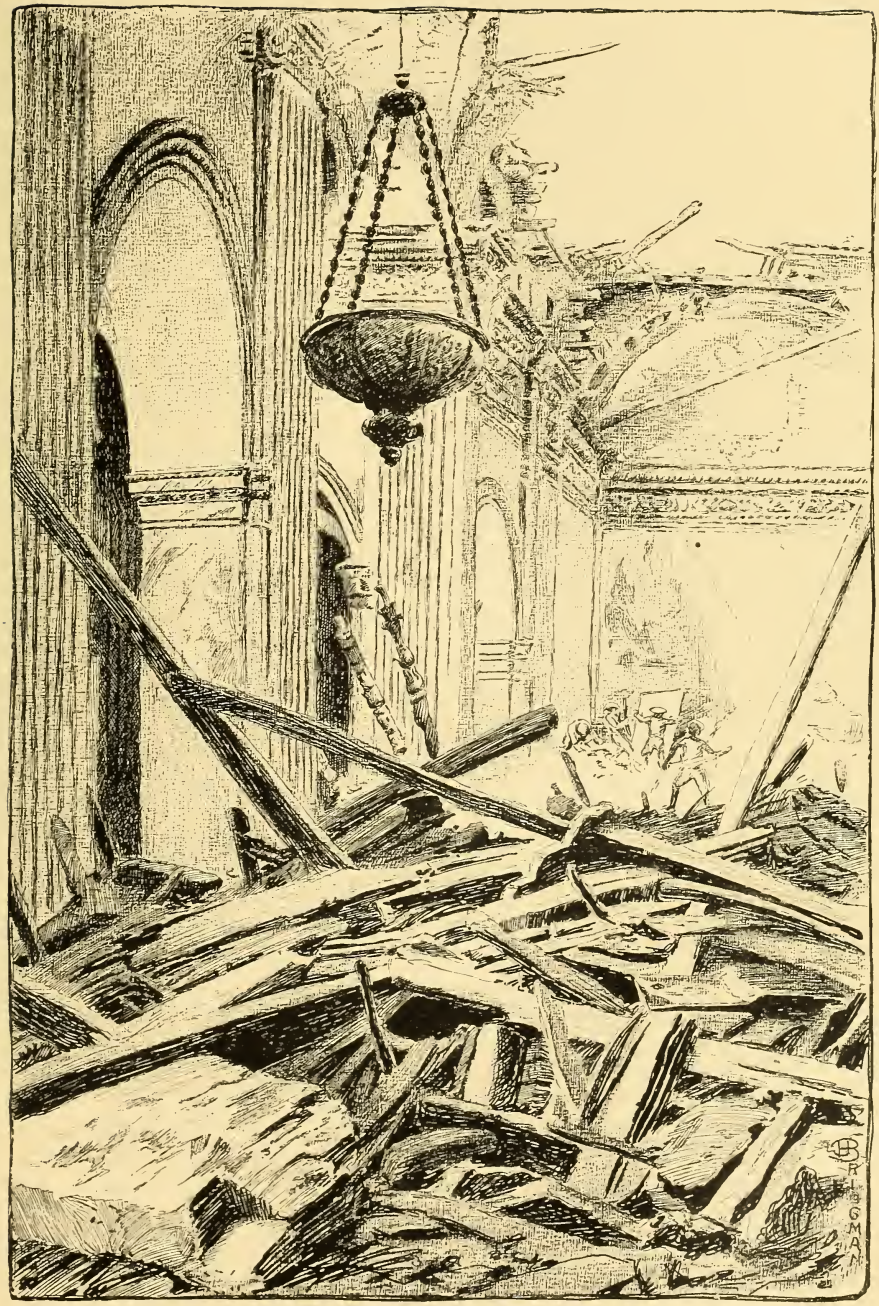
The tremblings grew more frequent and marked than the oscillations or waves of shock, especially after the first day, in which the general direction was north to south. The bed of the river Pasig was disturbed with an upheaving of a dark fluid of a sulphurous odor, but without injury to the bridges. In many places within the city the soil cracked, with the eruption of fine sand and dirty water.

While viewing the ruins, sixteen months after, I gathered, from members of my family and other eye-witnesses, some interesting details. After hearing the first sound, which was as if hundreds of carriages were being dashed to pieces on a broken pavement, an incomprehensible faintness was experienced, causing a feeling of nausea, with inability to fly from the

danger. It was as if one were on the deck of a vessel, tossed by the waves, instead of a building of stone or timber, on the ground; it seemed as if the essence of several hours' seasickness were concentrated into a second. Mingled with this came strange rumblings, as if rocks were rolling and resounding over deep abysses, and sharp clashings as of glass shattered, caused by the rolling of furniture on the bare floors, and the breaking of mirrors and chandeliers. When sense returned a rush was made to the stairs and balconies, into the court-yards, streets and squares, under arches, or wherever seemed a place of security.

The disturbance extended to the suburbs of the city, and in fact to most of the island, where the soil appeared like the waves of the sea. Trees were uprooted, and towns and villages, amid clouds of whitish dust, became a chaotic mass of ruins. Every animal exhibited signs of terror; pigs, dogs, poultry, even lizards, felt the impending danger, and united in loud and unnatural noises. Horses stopped in the street vehicles, standing with ears erect, with staring eyes, and stiffly extended legs, as if conscious of extraordinary peril. The natives would give no response to appeals for help, but, careless of consequences, were either seeking safety themselves, or were on their knees in the highways and squares, with other timorous Catholics around them.

After the calamity, fallen tiles left exposed the skeleton ribs of the house roofs; hanging beams and swinging rafters threatened to fall upon the passer-by. A suffocating dust filled the air; broken arches, leaning walls, blinds in fragments, piles of useless furniture, and shapeless heaps of stone, met the eye in every direction. Dwellings open to the sky, and general ruin, were everywhere. Stone houses were abandoned for the



CHURCH AT MANILA.

thatched huts of the suburbs. An earthquake undoes in a minute the work of centuries, and even in a few seconds makes a city look as if sacked by a besieging enemy. The silence is interrupted only by an occasional cry for assistance, or the crash of a falling building; man is exhausted, and inanimate nature sleeps after these geological catastrophes.

The first great quake in Manila was not without premonitory symptoms. Even as early as April and May commotions were noticed in the northern provinces of Luzon. The centre of disturbance seemed to be a long-extinct volcano in latitude sixteen degrees and twenty-two minutes north, between Lepanto and Abra, in the central Cordillera. At first weak and infrequent, in June they became more intense, extending north and south, and east and west; any apparent divergence from these points being probably due to the want of special instruments and errors of hasty and excited observation. In the beginning of July a few shocks were felt, but from the fifth to the fourteenth no news of any in the island had been received in Manila. On the fourteenth, at 12.53 P. M., the weather being threatening, as indicated in the northeast by an extraordinary fall of the barometer, the first shock was experienced in the city. In this there appeared to be two centres of oscillation combined; one was between east and south, whence the pendulum of the horizontal seismometer began to move, and the other between south and west, by which the first movement terminated; this was principally in a horizontal direction, the amplitude of oscillation being about five and one half degrees. The horizontal pendulum described a cross, arms of which intersected almost at right angles; the first from about southeast to northwest, and the second from

about southwest to northeast. The second oscillation was a violent one; the vertical movement registered was sixteen one-hundredths of an inch.

On the eighteenth, when the great shock took place, the movements of the seismometer were very intricate, as may be seen by examining the diagrams of Padre Faura of the Observatory, published in Manila at the time. On his authority it may be stated that only the greatest oscillation, from east to west, and the one most regular and without violence, indicates the true inclination of the buildings toward the west.

Of the three shocks, the first showed the greatest oscillation from east to west, the maximum width of seismic deviation being twenty-two degrees, or eleven degrees to each side; in the second, nearly at right angles to this, the deviation was nineteen degrees, and in the third, intersecting these two, sixteen degrees. The impulse, consequently, appears to have been from north to south; the vertical displacement was one and one third inches.

The inclination of buildings was not equal to the deviation of the pendulum; but it is impossible to measure the strain they must have undergone in such repeated and violent movements. Taking into consideration the horizontal and vertical oscillations, it is remarkable that their destruction was not greater. The pendulum, which had not ceased moving from the eighteenth to the twenty-first, in the three following days had considerable periods of rest.

It is not difficult to find the explanation of these movements, in a general way, in the rupture of the over-strained strata, with some elevation, but doubtless much greater subsidence in this region weighted by a chain of mountains, underlaid by large

volcanic cavities. The shock reached Manila in various directions and with differing violence, according to the complexity of the fractures, and the character and line of the strata which conveyed the impulses to the points of destruction. The preliminary shocks, preparatory to the great ones, and the phenomena noted by most competent observers, with accurate instruments, seem fully and naturally accounted for on the theory of secular contraction, and consequent folding, rupture, and displacement. This full statement of details will render unnecessary minute accounts of other earthquakes, and these will be briefly noticed hereafter.

CHAPTER XIV.

MANILA AND JAPAN EARTHQUAKES.

Incidents and accidents. — The cottage more safe than the palace; the boat on the river than a carriage on land. — The best way to build houses there. — Japanese earthquakes in Tokio. — Prof. Milne's book and opinions. — Explosive effects as a cause.

IN the midst of this commotion of 1880, it is said that the barometer gave no indication of atmospheric disturbance, showing that, in this case, at least, the cause was wholly terrestrial. The suburbs, particularly along the course of the river, suffered more than did the city proper.

Where my friends resided, in San Miguel, the shock was especially violent. The household were at breakfast, and of course left the table in a hurry, seeking the outside air, some by the windows, and some by the stone staircase; one was caught in the falling roof, and sustained injuries which required amputation of an arm at the shoulder. Had they remained at the table, no one would have been hurt; but, of course, the natural impulse, and usually the safest, is to get beyond the danger of falling walls and tiles. Most of the rear part of the house, on the river side, was so damaged that it remained for a long time untenanted. In San Antonio, near the city, for the length of more than four miles, and a width of three hundred and fifty feet, the ground opened in many places; some portions were raised five or six feet, and others were equally depressed.

The volcanoes of Taal and Bulusan, which had been quiet for many years, threw out much vapor, with an alleged diminution of the severity of the shocks in their neighborhood. Mayon took on at this time an unwonted activity, and continued to throw out lava, ashes and gases for more than two years. It is popularly believed that the great volcano acted as a safety valve, preserving the province, and perhaps the island, from a serious catastrophe. There could, however, scarcely be any general connection in this respect between the earthquake and the volcano, except that the former caused the latter, and not *vice versa*. It may have been that some local rupture from pent-up gases was at the same time prevented by this constant drain of material, and that the cavities produced by the emission of lava, predispose to an earthquake subsidence, when the stress and weight can no longer be resisted.

Amid all the confusion and terror the newspapers failed not of their duty to the public. The "Diario de Manila" went to press in the middle of the street, its building being considered unsafe. The city was turned into a tented field, and the river and bay were densely peopled. Everything that had wheels, or could float, was loaded with persons and property seeking safety. Palace and prison, church and shop, street and bridge, house and hut, barrack and hospital, were alike prostrated and rendered useless. The thatched hovel was of more value in such an hour than the mansion of stone; a boat on the river than a palace on land. Carriages with silks and jewels, carts with rich or homely furniture, the head-carried baskets of the Chinese, and the palm-leaf tampipis of the Indians, blocked the streets on their way out of the walled city. Fear brought pride and poverty into close communion; the quarrels and

petty grievances of the past were forgotten and forgiven in the all-absorbing common danger; but, like a supposed death-bed repentance, an earthquake reconciliation amounts to very little when the danger has passed.

The disasters closed on the twenty-sixth with a severe, all-night rain, accompanied with violent gusts of wind. This increased the loss in furniture and other property that was of necessity exposed to the elements. Most of the people in the thatched houses suffered from wet, and there was much sickness in consequence, especially among children and invalids.

Experience has taught that in countries subject to earthquakes it is necessary to build the houses low, with a foundation of volcanic tufa, whose many interstices render it elastic. Above all things, the structure should rest on wooden posts, incased or not in the stone, but independent of it; and for the heavy roof tiles should be substituted sheets of galvanized iron. Lightness and elasticity are sought for, and these the wooden, bamboo and nipa houses of the country have to such a degree that, with the aid of lateral supports, they may be regarded as nearly earthquake-proof.

Many violent earthquakes have occurred of late years in Japan, and one in 1880, the year of the last one in Manila. Interesting observations on the phenomena are given in the "Japan Weekly Mail" of October 8, 1881, by J. Milne, and by W. S. Chaplin, in the "Transactions of the Asiatic Society of Japan," April, 1878. These differ much from Mr. Perrey's results, and confirm in the main the views of Mallet, while at the same time they indicate a connection with astronomical and meteorological causes. In this paper it is claimed that

AT LUZON, MANILA.

earthquake phenomena have been most frequent when the sun was two hours east and eight hours west of the meridian, and when the moon was two and nine hours east and seven hours west, and least at the upper transit. Of one hundred and forty-three cases thirty-two were at conjunction of moon with sun, thirty-seven at opposition, and seventy-four at quadrature; in summer sixty-nine, in winter seventy-four; when the moon was north of the equator sixty-one, south eighty-two, and the maximum at seven and eleven hours after the moon's perigee, or when nearest the earth. These are taken from the records of the Tokio Observatory.

A severe earthquake shook Tokio January 15, 1887; one in Hawaii, and an eruption of Mauna Loa, occurred on the same day. The concurrence of the earth vibrations in these two remote places would seem to show that both are situated over the same fissure or line of weakness in the crust.

In searching for the origin of these and the Manila earthquakes we naturally turn to the volcanic districts; in Japan these extend from northwest to south-southwest, but most of the volcanoes are extinct, except for such eruptions of vapor and sulphurous hot springs as exist at Ogigoko. We know that there are geological "faults," indicating recent movements of the crust, and that they were preceded and followed by many lesser tremblings in one direction. The great shock in Japan was on February 22, 1880, from the north-northwest; that of Manila July 18, but from April signs of disturbance had been noticed in the northern provinces. It must be remembered that the Philippines are situated in the volcanic chain which extends from the Kurile islands, through Japan, to Java and Australia; both shocks may have been due to

the same progressive fracture from tension along this line of weakness.

Both in Tokio plain and in Manila, Mallet's statements were confirmed, that, in a rectangular building, the walls at right angles to the shock are most likely to be overthrown. In 1863 houses seemed to move in an undulating manner from east to west, the course being south; but when the movement is slight, the walls at right angles would sway back and forth, without coming down, while the others, contracting and expanding in their length, would give way at their weakest points, or in their various openings.

The latest authority on earthquakes is Prof. John Milne, above quoted, whose work, No. 55 in the "International Scientific Series," 1886, will be of extreme interest to all interested in the subject of seismology. He treats of the subdivisions of earth movements, with instrumental, mathematical, physical, and meteorological details that are quite out of place in a book for popular reading. His work pertains chiefly to Japan, where his observations were made, and he adopts essentially the views of Mallet, from whom he quotes largely. It is rather non-committal, as it enumerates among primary causes telluric and solar heats, and variations of gravitating influences. Among the secondary he places expansions and contractions of the earth's crust, changes in temperature and barometric pressure, rain, wind, solar and lunar attraction, and variations in the distribution of stress in the crust; afterward he calls the primary causes endogenous, and the secondary exogenous. The latter, he thinks, play a very subordinate part. He says, finally, that the majority of earthquakes are due to explosive efforts in volcanic foci, most of them taking place

beneath the sea, and due to the entrance of water through fissures to heated strata below. He admits that some are produced by the sudden fracture of rocky strata, causing "faults," attributable to stresses brought about by elevatory pressures; and some to the collapse of underground excavations. I am inclined to the belief that the explosions are not the cause, but the consequences of fractures of the crust.

In the "London Times" of August 7, 1884, is a communication from John Milne on the earthquake of Japan, in 1880, and that of England in April, 1884, in which he states that the maximum distance through which a point of the earth moved to and fro in the former was one inch, in the latter somewhat less. The intensity of the shock is not determined by this movement, which depends rather on the acceleration or suddenness of the motions. Movements may be large, but so slow as to be hardly noticeable except by instruments. They may be, on the other hand, not more than one tenth of an inch, and yet from their suddenness felt as very severe. The suddenness in the English one was equal to a rate of motion of two feet per second; so slow that persons saw buildings falling, but noticed no motion of the ground.

As earthquakes usually depend on displacement or rupture, the first indications commonly noticed are minute tremors (preparatory), with or without sound, and perhaps six or eight in a second; then comes the shock (the rupture), consisting of two or three back and forth movements of large amplitude, ending by a series of irregular movements, longer and longer as the disturbance dies out (the parts implicated settling to rest). At a distance nothing would be noticed but a series of slow pulse-like movements or waves; as on a water surface disturbed by a

stone, the outer circle is hardly distinguishable. It is difficult to record the whole duration, as the first movements are lost from their extreme smallness, and the last by their extreme slowness. The waves produced may be in all, and in complicated lines, according to the character of the strata involved. The earthquake soon classifies buildings as to stability.

CHAPTER XV.

ISCHIA, SPAIN AND THE RIVIERA.

Island of Ischia.— Bathing establishments.— Delightful summer resort for Neapolitans.— Earthquake of 1883 at night.— Deep seated and extended.— Great destruction of buildings and loss of life.— Worst at Casamicciola.— Made up of the tufas and lavas of the volcano Epomeo, an extinct crater.— Probably from subsidence.— Absence of volcanic phenomena.— Earthquake in Southern Spain in 1884.— Barometric changes.— Result of fracture in the mountain masses, and a weak coast line.— Northern Italy and Southern France.— Probably from fracture in the Apennines and Mediterranean basin, in 1887.

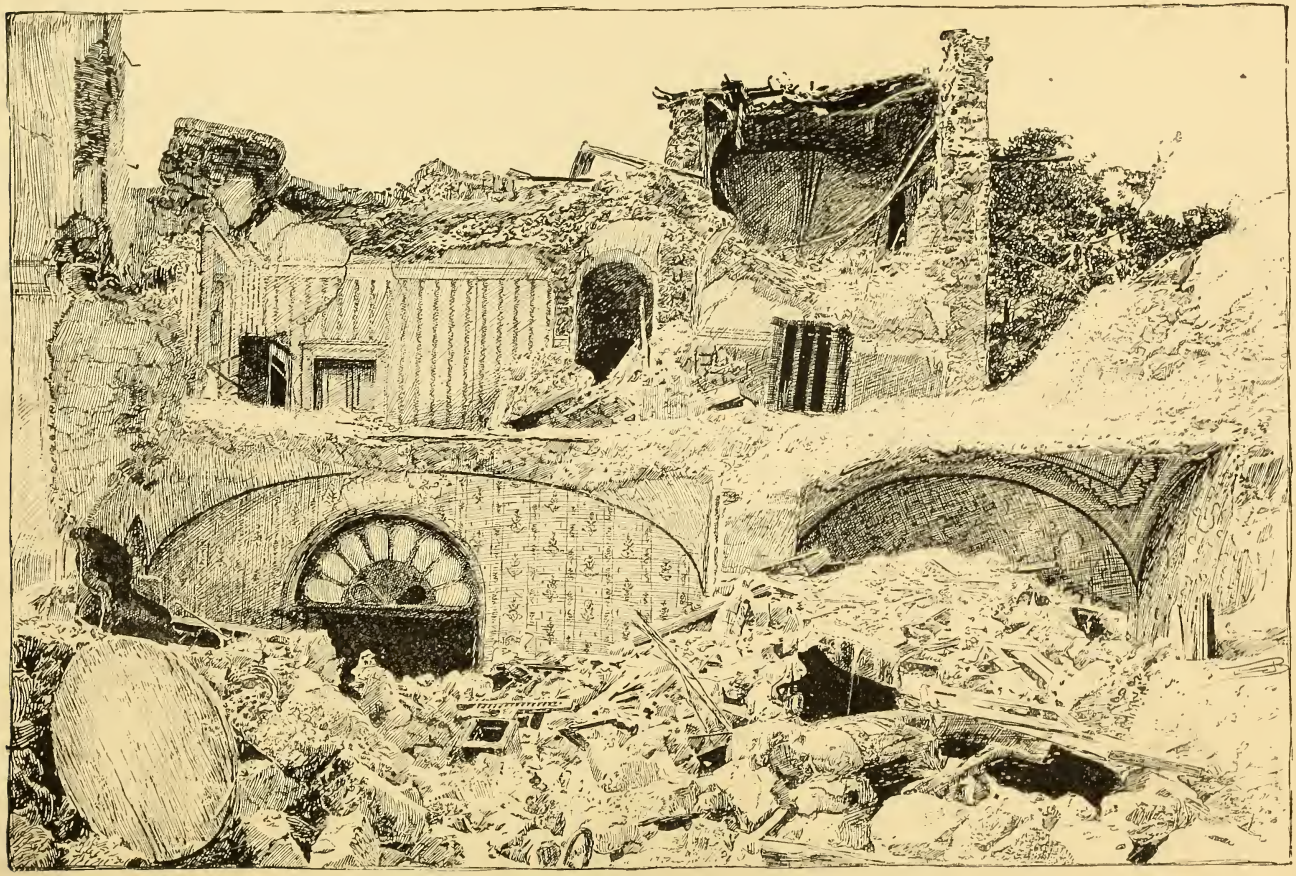
IF there were any place outside the tropics which can lay claim to be an earthly paradise, it was the beautiful island of Ischia (*Isola Bella*), the "Pithecusa" of the ancients. It is the largest island of the bay of Naples, having a circumference of about twenty miles, and thirty thousand inhabitants, mostly fishermen, brick-makers, and cultivators of grain, vines, and fruits.

From a distance it looks like a double-crested pyramid, the highest point being the extinct volcano, Epomeo, about twenty-six hundred feet high. This is much older than Vesuvius, and was once the principal volcanic vent of the region. There are records that its inhabitants, five centuries B. C., were driven away by its eruptions and accompanying earthquakes. Other destructive eruptions were 92 B. C., and until the third century A. D.; Homer and Virgil allude to it as the prison house of one of the giants, prostrated by Jupiter. It was last active in 1301.

At some points the island-sides are steep and rocky; at others are gently sloping beaches; but everywhere it is picturesque. It is wholly volcanic in structure, with the exception of certain elevations of marine clays, derived from pre-existing volcanic matters.

The island is about one and one half hours' sail by steamer from Naples. Travellers generally go as far as Casamicciola, and rarely beyond. The first landing-place is the town of Ischia, which has about sixty-five hundred inhabitants. Its harbor is an old crater. The principal road extends along the shore, over the north half of the island, by Casamicciola on the east, Lacco on the north, and Forio on the west; towns all nearly destroyed in July, 1883. The views along these roads are exceedingly beautiful. Near Ischia are famous warm baths, of late less popular than those of Casamicciola. Fifteen minutes by steamer, or an hour's donkey ride, will bring the traveller to Casamicciola, a town of some four thousand inhabitants, where in the summer were always to be found a crowd of invalids, and a few pleasure-seekers enjoying its celebrated warm baths. From the landing, a ride of fifteen minutes by donkey or vehicle brings the tourist to the hotel.

The town is at the north base of Epomeo, on two hills, with two more to the east, each seven hundred and fifty and eight hundred feet high. The sides of the mountain and the terraced valleys were studded with hotels, villas, and bathing establishments, all depending for support on the saline, alkaline, sulphur, and carbonic acid waters, gushing out from rock and soil, with temperatures varying from seventy to one hundred and seventy-five degrees Fahrenheit. The magnificent views of the Mediterranean, with Vesuvius in the distance, backed by the



PICCOLA SENTINELLA AT CASAMICCIOLA, 1883.

snow-capped Abruzzi, the genial climate, the picturesque situations, the blue skies and the golden sunsets, the luxuriant verdure, the bright houses, the fine hotels and the healing waters, made this semi-tropical dreamy island one of the most delightful of summer resorts. To-day it is little more than a heap of crumbling ruins, the tomb of many unburied dead, and probably never again to be a popular watering place. Half an hour's walk brings the visitor to Lacco, on the north side of the island, with some sixteen hundred fishermen as residents, and another hour to Forio, on the west, with six thousand three hundred inhabitants; both were dependent on the summer visitors to the bathing establishments, though many wealthy proprietors resided at the latter. Both are now in ruins.

Among the bathing establishments some were fitted up in the most luxurious and Pompeiian style. The "Monte della Misericordia" was an extensive, and always crowded establishment, exclusively for the poor, founded in 1600 by a society of nobles, who annually sent from Naples, free of expense, many invalids, who were cared for by skillful physicians.

Among the hotels the most aristocratic was the "Piccola Sentinella." It was very large, and was built in terraces, in a charmingly picturesque situation, surrounded by orange groves, olive trees, and flowers and flowering shrubs of every hue. The "Grande Sentinella" and the "Central" were more democratic. The villa "Balsamo" stood in the midst of beautiful gardens, and beside these were many private villas and boarding houses.

The shock of July 28, 1883, occurred at 9.25 P. M., so that utter darkness added to the horror of the scene, and most of the residents, a large number of whom were invalids, were in

their houses. It lasted twenty seconds, during which Casamicciola, Lacco and Forio were nearly destroyed, with the loss of two thousand lives. Ischia suffered very little. That the disturbance was deep-seated and extensive is shown by the fact that it was indicated by instruments at Rome nearly two hundred miles distant. The shock at first was vertical, and then the wave was propagated in various directions according to the nature of the soil; the cracks in the buildings indicated a prevailing vertical movement.

The most heart-rending scenes occurred in Naples the next day, where the hospitals were crowded with the wounded, and the dead-houses filled with the bodies of the victims. Of the bodies recovered from the ruins most were so disfigured that they could hardly be recognized except by clothing. The majority of the killed were women and children, and invalids of high and low degree. All the police force was killed, rendering organized aid almost impossible in the general terror. Many persons who might have been saved by prompt assistance perished beneath the ruins.

Of the foreigners saved the greater part were those who were at the theatre, where, singularly enough, the play was a burlesque, which opened with an earthquake scene. Survivors passed the night in darkness and fear, not daring to move, even to help those calling for aid among the ruins. A force of soldiers arrived the next day (Sunday), and rescued many sufferers even as late as Monday morning. Scarcely half a dozen houses were left standing. About forty persons were entombed in the "Piccola Sentinella," of whom only one fourth were saved. Temporary wooden huts were erected for the houseless, and government and private aid freely given. No Italian convul-

sion has been so destructive since A. D 79, except the Calabrian one in 1783, which was felt all over Europe, and is said to have killed sixty thousand people. This was no doubt caused by a sinking, similar to that which I believe produced the Casamicciola earthquakes of March, 1881, and July, 1883.

The geological structure of the island throws some light on the nature of this earthquake. The oldest strata are the greenish tufas of Epomeo, overlaid by trachytic lava. Over this are extensive beds of clayey decomposition of this tufa under water, upon which Casamicciola was built; the most recent are gravelly clays, containing many marine fossil shells of species now living, indicating a comparatively recent submergence and subsequent elevation. Hot springs, jets of steam and sulphurous gases abound, especially in the northern part, on a line running from Ischia west to Forio, passing under Casamicciola, which is about midway.

Signor Baldacci has expressed the opinion that there are two lines of cleavage; one as above given, and the other from Lacco to the southern extremity of the island, crossing the first at Casamicciola. Prof. Rossi thinks that there is a superposition of the crater of Epomeo upon another older and submarine one. The latter theory seems most probable, and would confirm Prof. Palmieri's theory of subsidence. The last better explains the slight preparatory shocks and rumblings, and as well accounts for the irregularity in heat and quantity of the springs and the activity of the gas-jets.

Casamicciola was built almost entirely on the non-elastic clay strata, and Forio on the tufa. That part of Lacco on the more elastic trachyte, and Ischia, suffered little. In the trachyte not only the direction, but the velocity, of the earth-wave was

changed. Other lesser shocks and rumblings occurred afterward; as what I regard as the sunken strata settled to comparative fixity. These can hardly be explained by the awakening of any residual activity in Epomeo, which has been quiet for six centuries, except for its minor phenomena of hot springs and jets of steam and gas.

According to Palmieri, great caverns (not the petty ones in the plastic clay) worn by heated waters and corroding gases, at unknown, but great depths, fell in from loss of support, from vertical or lateral pressure, and thus produced the earth shock. The causes which originated them act at present, and will doubtless continue; so that prudence says, "flee from, and return not to, this beautiful but treacherous paradise."

Two great lands slides on the steep north side of Epomeo, and fissures in the ground on the south slope, favor the subsidence theory. Though the roads were destroyed, and the houses levelled, the former showed no signs of sinking, but they were fissured longitudinally and transversely; the cause was too deep for that. There was no evidence of the escape of lava, or unusual amounts of steam or gases; no sudden rising of the soil, or sign of subterranean explosion. Additional facts in favor of this catastrophe being rather a subsidence than a volcanic disturbance — a repetition, on a far larger scale of that of March, 1881 — are the local character of the destruction, and the subsequent lesser ones even to July, 1884, and again in August, 1886. The Ischian earthquake of March, 1881, was, according to Dr. Lasaulx, but slightly felt on Procida, and not at all on the mainland. From this he infers that its origin must have been at a less depth than the bottom of the inter-

vening strait. It occurred in an east and west oval, north of the Epomeo centre. He maintains that it was due not to volcanic activity, but to subsidence, from hollows removed by the numerous hot springs, whose temperature is raised before and during the catastrophe; that of 1883 was far deeper.

The earthquake in Southern Spain, already mentioned, occurred just before nine P. M. of December 25, 1884. There were slight premonitions on the morning of the twenty-second, far extending, even to the Azores; the shocks were followed by a long series of oscillations up to February, 1885. The worst shock was on Christmas day, and was plainly felt in Madrid. In the southern provinces along the Mediterranean, especially at Granada and Malaga, there was great loss of life, and destruction of property. There were many landslips and crevasses, which seemed best explained by deep-seated subsidence. An unusually high atmospheric pressure prevailed over Spain in the first half of December, while on December 20 a heavy storm, with unusual barometric depression, passed over from the northeast, reaching the Mediterranean on the twenty-second, or a few days before the principal shock.

In a paper contributed to "Nature," Mr. MacPherson writes: "The Mediterranean watershed at Andalusia shows two great mountain masses, chiefly of archaic deposits; both run in a series of faults and folds from southwest to northeast, and between them is an interval filled with primary, secondary, and tertiary deposits, in the middle of which, in the later ones, is a series of archaic ridges running northwest to southeast; and evidently a part of a greater archaic formation, separated from adjoining rocks by a subsidence on both sides. From frequent oscilla-

tions this isolated portion has been covered by a thick mantle of sediment, and its structure is the result of the great fracture which crosses the peninsula from northwest to southeast. The most violent shocks were in this very belt, broken by the secular disturbances of the crust of the globe, to which Prevost, LeConte, Mallet, and others after them, have drawn attention as frequent, if not the principal causes of earthquakes. In the Spanish shocks we see the possible influence of barometric changes in modifying pressure of the surface. These, in connection with heavy mountain masses on a longer line of fracture, and on the edge of the weak coast line of the Mediterranean, sufficiently account for the phenomena without any known explosive or volcanic accompaniments. Whether subsidence or elevation prevailed, the fact of rupture and displacement, with consequent shock, in a much faulted region, seems clearly made out."

On February 23, 1887, between six and ten A. M. occurred a series of heavy shocks over Northern Italy and Southern France. They extended from Genoa to Marseilles, along the Mediterranean coast, and included Nice, Cannes, Mentone, Monte Carlo, and their vicinity. They caused a loss of at least two thousand lives, and much valuable property; the so-called Italian Riviera suffered most. The longest single shock seems to have been twenty seconds, but they occurred at varying intervals for several hours, and even for two or three days. The loss of life in the mountain villages was largely due to the houses being placed on terraces built out on their sides, a slight disturbance of their foundations being sufficient to precipitate them, with all their contents, into the valley below, and to render escape or rescue impossible.

The phenomena, detailed with such horrifying minuteness in the daily papers, were in no wise peculiar, and resembled very closely those attending the Charleston earthquake of 1886. The cause and origin do not seem to require much discussion; the seat or centre of disturbance was evidently in the deep strata of the Maritime Alps and the connected Apennines, bordering on the shores of the Mediterranean basin. The movements apparently extended even to Avignon and Geneva, showing a very wide area of convulsion. It is stated that the seismoscope in Washington recorded a disturbance at 7.50 A. M. on the twenty-third instant; but there is no certain evidence that this was a transmission of the European wave across the Atlantic. It was probably also a mere coincidence that there occurred an annular eclipse of the sun on February 22, on account of which the Berlin papers prophesied unusual seismic phenomena, from the combined influence of the sun and moon on the earth.

The supposition has been made that the shocks were occasioned by the fracture of some part of the crust of the earth in the region implicated, from the secular cooling of our globe, and that the immediate cause of this fracture was the weight of the immense mountain chains of the Alps and the Apennines on the line of weakness along the border of the deep Mediterranean. If this is correct further shocks may be expected, similar to that which occurred at Charleston, until the strata come to a stable equilibrium, after which they may remain at rest for centuries. This is also the belief of M. M. Flammarion, Mouchez, and Daubrée, as to the recurrence of the shocks. It is probable that there is a geologic fracture or line of weakness in the Mediterranean basin itself, parallel to

the Ligurian coast. For a considerable period before the disturbances there had been many sudden changes in barometric pressure, chiefly from low to high. This may in many cases explain the dizziness, oppressive breathing and nausea, which so often accompany and render perceptible an earthquake shock.

CHAPTER XVI.

AMERICAN EARTHQUAKES. — THE MISSISSIPPI VALLEY, AND THE ATLANTIC SEABOARD.

New England earthquakes for two hundred and fifty years. — Shock at Panama in 1882. — Inauspicious for an isthmus canal. — In Mississippi Valley. — The Charleston earthquake of 1886. — Severest and most extensive in United States. — Surface indications. — Direction. — Probably deep-seated, and connected with a dislocation in the Appalachian range, and a displacement of the coastal plain. — Perhaps associated with subsidence in the lowest strata. — Speculations.

THE fact that earthquakes of considerable violence occur in North America, both within and beyond volcanic centres, is generally known.

In New England, in two hundred and fifty years, ending in 1870, there were two hundred and thirty-one recorded earthquakes, and doubtless quite as many unrecorded. Of these one hundred and forty-eight took place in the winter months, seventy-four in the summer, and nine are not specified. Some have already been alluded to in previous chapters.

In 1885 fifty-nine earthquakes were recorded, more than two thirds of which were on the Pacific slope of the United States and British Possessions. From 1872 to 1883 three hundred and sixty-four were recorded; one hundred and forty-seven on the Atlantic slope, sixty-six in the Mississippi Valley, and one hundred and fifty-one on the Pacific slope.

On September 7, 1882, a very severe shock, lasting a minute,

occurred in Panama, beginning at 3.18 A. M. Walls tumbled into the streets. The front of the old cathedral was ruined, and its tottering arches were afterwards demolished; the court house, with its massive stone columns, became a heap of ruins. The Canal hotel, purchased for the company for two hundred thousand dollars, swayed and cracked, with much damage to its walls; furniture and glass were broken. The people rushed out-doors, seeking safety in empty spaces, as if all danger was from above; and the greatest terror prevailed till daylight appeared. The ships in the bay felt the shock, as did the islands and the suburbs. It did not extend into Nicaragua nor South America, the wave travelling in a northeast direction. It is said the barometer did not fall. It was the most severe earthquake ever known on the isthmus, and had it lasted a few seconds longer, would have totally destroyed Panama. What effect this would have had in the mountains and river valleys in the course of the proposed canal, may easily be imagined; earthquake and financial shocks, climatic and meteorological obstacles, seem to combine to prevent inter-oceanic transit at this place.

After the Panama disturbance, on September 27, there was a series of shocks in the Mississippi Valley, in a non-volcanic region, which seem to point rather to atmospheric than geologic causes, though both probably had a share in their production. They happened at a time when a great aërial disturbance, with sudden and large barometric fluctuations, had prevailed over the temperate and tropical zones of North America.

In a recent report to the British Association, Mr. George Darwin shows that when the barometer rises an inch over a land region as large as Australia, the increased load of air sinks

the entire continent two or three inches below the normal level, while over an equal oceanic area the water surface may be depressed a foot or more. It is probable that to such transient changes of stress many of the slight vibrations of the crust may be due, and this may be the explanation of the tremors in the Mississippi Valley.

In 1812 similar phenomena took place in the same region, though of much greater severity, namely: in Indiana, Illinois and Missouri; in fact the disturbance involved nearly half the hemisphere, and ended in the upheaval of Sabrina, one of the Azores, three hundred and twenty feet above the sea, the eruption of St. Vincent volcano, and the destruction of Caraccas, with ten thousand people. New Madrid, Mo., was one of the foci of this extended earthquake, in which the shocks were repeated almost every hour for months in succession. It was noticed that on the night of the Caraccas earthquake the subterranean forces at New Madrid were most intensely active. According to Dr. J. W. Foster, near the latter, fissures six hundred feet long and twenty broad formed, out of which water and sand were ejected to the height of forty feet. The shocks were severely felt in the Ohio Valley, and over a wide area of the Mississippi basin. The shocks in 1882 are said to have come from the west, as did those in New Madrid in 1812. Had they been of similar severity, the cities of this river valley would have been utterly destroyed.

The earthquake which desolated Charleston, S. C., probably originated in Eastern North Carolina, where it seems to have been noticed, according to Prof. Powell, at 9.50 P. M., August 31, 1886, reaching Charleston a few minutes before 9 P. M. As it occurred at night, the terror and confusion were

extreme, people leaving the falling and trembling houses, and seeking refuge in the widest streets and squares, clad in most cases only in their night clothes.

This was the most severe shock on record in the United States, and affected the greatest area, namely: nine hundred thousand square miles, or one fourth of the country. This included a region extending from the Gulf of Mexico to the great lakes and Southern New England, and from the Atlantic seaboard to the Central Mississippi Valley. Its origin was apparently along the line of post-tertiary dislocation, on the eastern flanks of the Appalachians, especially where it crosses North Carolina. From this it spread rapidly in all directions, with a velocity varying from twenty-five to sixty-five miles a minute. It was very severe at Charleston, almost destroying the city, with considerable loss of life. At least nine tenths of the buildings were injured; many beyond repair. The frame and brick houses swayed and fell, offering much resistance, while the wooden structures simply collapsed.

Among the surface indications were noticed landslides, crevasses, and fissures, some running north and south, and others east and west. Out of these mud and sand were ejected, and in some cases small stones. There was no tidal wave, nor any alteration of level of land or depth of sea, although it was noticed off the harbor of Charleston. Rails on the railroad were bent in a snake-like fashion, indicating both a vertical and lateral force. That this force was not deep-seated is shown by the fact that the flow from artesian wells, four hundred feet and more in depth, was not disturbed.

It is said that slight premonitory symptoms had been noticed for several days before the shock, though what these were, be-

sides certain obscure rumblings, does not clearly appear. The evening of the earthquake had been warm, still and close; the sky was lurid, and the earthquake was accompanied by a peculiar scorching heat; but these were doubtless mere coincidences only, and such as might be expected in the month of August. There were no sudden barometric changes, either above or below the normal standard. There were many shocks, at varying intervals, for months after.

The direction was, in general, north and south, deflected to east and west, according to structure and arrangement of the strata along which the wave was propagated. Some wells and springs were affected; drying up, or new ones opening. It is stated that the Pennsylvania natural gas wells were diminished, and that a geyser in the Yellowstone Park, quiet for four years, burst into action; but these might also have been mere coincidences. Certain sulphurous fumes from fissures, and brackish tepid water from rents sixty feet long and of uncertain depth, are no indications of volcanic action, and are simply the result of fracture, without any necessary sinking. The shock was probably transmitted along certain lines of great rock masses, or lines of weakness.

From the great area affected by this disturbance, it has been asserted that the cause could not be a local one, and from the fact that an earthquake happened in Italy and Greece on August 29, its origin has been placed in the Mediterranean, the shock travelling across the Atlantic at the rate of about one hundred miles an hour. But the shocks have been too many and too long continued, to be explained by any such distant cause, and there is a far more probable one nearer home. From the direction of the shocks in Summerville and Charles-

ton being from southeast to northwest, others have maintained that the centre of the disturbance was beneath the ocean, and reached the Atlantic coast from the line of Bermuda. There seems no valid reason for this opinion when we remember the geology of the region affected.

According to the experts of the United States Geological Survey, there is a line of weakness, beginning south of Raleigh, N. C., and extending along tide-water to Richmond, Va., Washington, Baltimore, and Troy, N. Y., marked by displacement which has long been known; characterized by fissures and faults, near which are found the sources of the principal rivers of the Atlantic slope; and it is one of the chief points to determine the relations of the origin of this earthquake to this line of weakness. The constant removal of the land masses by rains and rivers, and their deposition and overloading of lakes and seashores, localize the stress and consequent rupture of the crust, from the shrinking of secular refrigeration. There seems little doubt that this earthquake had its origin in the displacement, especially deep-seated subsidence, in the Appalachian system in North Carolina.

It would be unwise to theorize or to dogmatize at present on the origin and cause of the Charleston catastrophe. Volcanic phenomena, it is agreed, had no connection with it. On the land slide supposition, the great coastal plain of fragmental rock on the eastern slope of the Appalachian chain, embracing an area of nine hundred thousand square miles, slipped seaward, and produced the earthquake. On the subsidence theory, maintained by Prof. Mendelhall, it was the result of a readjustment of the crust of the earth to its shrinking nucleus, in this instance determined by the weight of the high tide acting on the weaker shore line.

The time has not arrived for a full understanding of the phenomena; many observations and statements, not always reliable, must be compared. Complete agreement of opinion is not to be expected; each scientist is most likely to have his pet theory, and will doubtless find much that can be interpreted in its favor. We know comparatively little, as yet, of the dynamics of the globe, and it becomes even the most expert to express their opinions in a very guarded way. It is to be hoped that much needed light will be thrown upon the causes of earthquake disturbances in non-volcanic regions by the Charleston catastrophe.

CHAPTER XVII.

CONCLUSIONS.

Similarity of volcanic and earthquake laws of occurrence. — Sensations during an earthquake. — Feeling of utter helplessness. — Not mysterious, though they cannot be foreseen nor prevented. — Not wholly bad. — Effects of a great cosmic force, which we call "gravitation." — The future of our earth and the solar system as deduced from the study of the moon. — A French speculation. — Law everywhere reigneth.

FROM what has been stated in the previous chapters, the reader will be prepared to consider the following conclusions, drawn up by Prof. Judd from an examination of the records from remote antiquity in the matter of volcanic eruptions, as applicable also to earthquakes; these last being regarded as due to displacements of the crust of the earth from causes sufficiently explained:

I. A long period of quiescence is generally followed by an earthquake, in countries liable to them from special causes, of unusual severity.

II. A long-continued or violent series of shocks is usually followed by a prolonged period of quiet, inasmuch as the displaced strata have come to rest, and would be likely to remain undisturbed, perhaps for centuries, according to the characters of the strata involved.

III. Feeble and short quakes ordinarily succeed each other at brief intervals. Petty dislocations, which effect but little in the

way of displacement, would most likely be frequent in proportion to their insignificance.

IV. The violence of a great earthquake is generally inversely proportional to its duration; the destructive shock usually does its work in less than half a minute, while the smaller rumblings and tremors may extend over hours.

There is something preternaturally terrible in the earthquake; when the earth, which we think the emblem of solidity, trembles under our feet, and geological convulsions, the most destructive agents of the past, threaten us in the present. The sensation is so beyond experience, and the feeling of powerlessness so overwhelming, that, amid the crash, man looks hopelessly around, and can simply bow the head in silent, motionless despair, as if expecting every moment to be buried in the ruins. With the cries and groans of the terrified people in the houses and in the streets, are heard the dull sounds of falling buildings, and appalling subterranean rumblings, and the thoughts of all are turned, where they always are instinctively, in times of unexpected, inexplicable disaster, Godward. When the earth is thus moved by invisible hands, each moment seems a year, and, as when death appears suddenly imminent, the events of a lifetime pass in an instant before the eyes of the soul.

It is a novel and a terrifying sight to behold houses reel like a drunken man, as the earth-waves reach them; it is more like the disturbed dreams of fever, or the scenic display of the drama, than any conception of reality. Earthquakes are of every degree of intensity from the hardly perceptible tremor, insensible except to delicate instruments, to the fearful risings and fallings, like the waves of the sea, that throw down the proudest structures as if they were toys of straw.

Earthquakes can no longer be regarded as mysterious dispensations of Providence, inflicted upon man in punishment for individual or national sins. We know, or we think we know, that their nature is that of a terrestrial wave of geological origin. In some cases they are due to explosions of steam or other gases beneath the surface; in others, and probably in most, to displacement, rupture, or subsidence of the crust of the earth, consequent on the cooling and shrinking upon the nucleus. Both are in some instances modified, and even precipitated, by barometric, and possibly other meteorological changes. We believe that they occur from the long-continued, silent, and slow forces of contraction and fracture, sometimes paroxysmal, but always according to dynamic laws, not ordinarily influenced by any explosive accompaniments. And we can have the comforting assurance, or at least the hope, for coming ages, of the gradual diminution of their energy as the crust becomes thicker and more consolidated, and the centre cooler.

There seems no great mystery about the phenomena; only from their occurrence in the dark depths and abysses of our planet, we must allow our imaginations to picture for us the horrible din and violence of the subterranean disturbances. As we cannot frame definite laws for the equal cooling and contraction of a globe of heterogeneous materials, we cannot prophesy where a line of weakness or fissure will take place. We cannot tell in advance where a rupture of elevation or subsidence will occur, and hence we cannot now, and probably never can, forecast an earthquake. This seems a poor result of our boasted knowledge of the nature and causes of these disturbances; but by studying their effects, we may mitigate somewhat the amount of destruction, suffering, and loss of life, by properly constructed dwellings.

In volcanic regions the volcano and the earthquake appear as twin monsters, distinct, though related; the progeny of mother earth and the force of gravity. Like mythologic steeds they traverse the globe, displaying their glowing breath in the lava stream and the fiery vapor; we feel their heart-beats in the pulsations of the ground beneath us; we hear their voices in aërial explosions and subterranean rumblings; we see their desolating footsteps in Manila, Granada, Java, Ischia, and recently in our own Charleston. This last is coming pretty near home, and shows us how fragile is the crust on which we live, how liable to mar the symmetry of our earth, and shatter the ornaments and excrescences thereon, which we style cities and towns, and which, here, at least, we flattered ourselves were as durable as the stones and bricks of which they were built.

Like the volcano, the earthquake is not wholly bad; there is no apparently dark picture of human suffering and misfortune which has not its bright and cheering side. The tornado and the freshet are at times destructive, but the ordinary peaceful circulation of air and water are none the less a blessing. In like manner, the subterranean forces occasionally spread calamity over a region, but they are necessary to supply and rearrange the materials lost by denudation, and to render our planet habitable. The volcano and the earthquake are only insignificant and local manifestations of a cosmic power which has in all time rent the earth's crust, leaving the mountain chains as the scars of its deep wounds — terrible, but salutary — indispensable, indeed, to the continued life of our globe. This single great cause of the volcano and the earthquake we call "gravitation," but of the essential nature of this cosmic

power we know nothing. We name and define, but comprehend not.

From the study of volcanic phenomena, especially on the moon, and those of earthquakes, scientific men of eminence have ventured to prophesy the future of our earth, opening to the imagination vistas of sublime and awful catastrophes, ending in the death of this planet and the destruction of all life upon its surface; a type of the final doom of the whole solar system.

According to Prof. Proctor, the moon is older than the earth, and in its motions independent. We may see in our satellite what the earth may become, if it goes on cooling at the present rate, in about twenty-five hundred million years, its present age being some five hundred million. Our planet therefore bears in its bosom the seeds of decay and death; slowly but surely it is parting with its vital heat; the volcano and the earthquake are the symptoms of final destruction as a planet, the first as it were the breathing, the last the paroxysmal condensation of the tissues of our bountiful mother, now in the prime of life. The earth has already passed through the vaporous or sun stage — the fiery stage, like Jupiter and Saturn. It is now in the life-supporting stage. Afterward, in its old age, it must dry up like Mars and Mercury, and finally will die, like the moon, with entire absence of water, atmosphere, and life, and with great diminution of volume.

A writer in "La Correspondance Scientifique" supplements this by the following speculations, which need not excite any alarm for many ages: "As the cooling progresses, a sheet of snow and ice, from north and south, will descend from the mountains upon the tablelands and the valleys, driving before

it life and civilization, and covering forever the cities and nations that it meets on its passage. All life and human activity will press insensibly toward the intertropical zone. St. Petersburg, Berlin, London, Paris, Vienna, Constantinople, Rome, and the great cities of the new world, will fall asleep in succession under their eternal shroud. During very many ages equatorial humanity will undertake arctic expeditions to find again under the ice the place of Paris, Lyons, Bordeaux, and Marseilles. The sea coasts will have changed, and the geographical map of the earth will have been transformed. No one will live and breathe except in the equatorial zone, up to the day when the last family, nearly dead with cold and hunger, will sit on the shore of the last sea, in the rays of the sun, which will thereafter shine here on a dead, cold earth, revolving, like a satellite moon, about a sun unseen by mortal eyes, and distributing to an extinguished planet a useless heat."

What may thus happen to our earth will be the fate of the other planets of our solar system, in their turn; and, as Campbell says in his "Last Man"—"The Sun himself must die."

But, even then, when our whole solar system is blotted out from the heavens, we may not approach, in an appreciable degree, in the most daring flights of the scientific imagination, the immensity of space and the infinity of time, over which presides the eternal All-Father. Let us, then, with humility and trust, take to ourselves this lesson from the volcano and the earthquake: to fear nothing from the "crash of worlds;" for law reigneth in the heavens and the earth, and in the universe that He hath made.

ADDENDA.

THE volcanic disturbances of 1887, though numerous and in the usual localities, have not been of such severity as to call for special notice.

The most noted have been in Mexico; but these offer only additional confirmation of the theory of their nature and causes maintained in the preceding pages. Vesuvius, Etna and Mayon have had their irregular periods of increased activity; Kilauea has displayed occasional energy in the "Lake of Fire," but Java, New Zealand and Iceland have been comparatively quiet. The newspaper stories of the Mexican eruptions have been greatly beyond the truth, as might be expected from the tendency to exaggeration, inaccuracy of observation, and hasty generalization inseparable from the accounts of ill-informed, careless and marvel-loving correspondents. No new principles, nor invalidation of the old, nor departure from the long-known lines of fissure in the earth's crust, can be deduced from the volcanic history of the year 1887. Only in Mexico have there been any well-authenticated earthquakes, and these have invariably preceded the outburst.

During the last half of 1887, the following have been the principal earthquake shocks, the world over, chronologically arranged.

June 3: A sharp shock passed over the greater portion of Northern California and Western Nevada, between two and three P. M., doing considerable damage in poorly built houses, and

changing the temperature and the amount of flow in some of the hot springs of the latter State. It is stated that the marble quarry in Mono County, Nevada, was practically destroyed, the stone having been broken into pieces no larger than a foot square. It was of this disturbance that the Piutes are reported to have given the following characteristic description: "Ground heap sick — heap belly ache — no good."

June 18: A severe shock was felt at Summerville, S. C., about 10.30 A. M.; the most prolonged since October, 1886. It was faintly perceived in Charleston. Several lesser tremblings have been noticed even to the end of the year, and more may be expected until the dislocated strata come to a state of rest. These phenomena also point to the comparatively local origin of the disturbing cause.

June 30: At about five P. M., a very distinct shock was experienced in New England, passing from Grafton, Vt., and Bellows Falls, south and east to Concord and Manchester, N. H., shaking houses and breaking furniture, but without serious damage. It lasted about fifteen seconds, and was said to have been accompanied by a rumbling sound. Its origin was evidently on the slopes of the Green Mountain range.

July 19 and *August* 29: Early in July the town of Bavispe, Mexico, was so completely destroyed that most of the inhabitants fled. Soon after a still greater calamity occurred at Bacariac, a town of twelve hundred inhabitants, about twenty miles distant; by a succession of shocks this town was reduced to heaps of ruins; the loss of life was small, as most of the people had deserted the region from fear. Near the Sonora line the land was so broken up that travelling was almost impossible, and the stockmen lost great numbers of cattle; springs

appeared in new places, and the old ones were dried up. There were shocks almost every day for some weeks, fissuring the ground in all directions.

On August 29, the weather being warm and the air damp, at 6.45 A. M. there was a sharp earthquake of about thirty seconds in the City of Mexico, felt chiefly in the suburbs. It was especially noticed at the United States Legation, and at the residence of President Diaz. People were much alarmed, running from their houses, and falling on their knees in the street, praying to the Virgin. It was not, however, especially severe for that region.

August 2: At 12.37 A. M. a slight shock was recorded at Nashville, Tenn., extending to Evansville, Ind., and St. Louis, Mo., and generally through Southern and Central Illinois. It lasted about eight seconds, but did no noteworthy damage. From the different directions of its estimated course it is evident that the central focus was in the mountains of Tennessee, whence it diverged in various lines according to the nature of the strata involved. In Kentucky, it is stated that a tract of more than two hundred and fifty acres of fine farming land in Trigg County sunk five or six feet below the level of the surrounding country, this space having been afterward filled to the depth of three feet by water from springs opened by this earthquake. The region is generally low and swampy, and there was a large pond in the vicinity.

September 23: A severe earthquake shock, lasting half a minute, was felt at Santiago de Cuba; this was followed, in the course of an hour, by two lesser shocks. The disturbance was noticed also at Kingston, Jamaica. No volcanic phenomena occurred, and the cause was doubtless a displacement along a

line of fissure, originating in the great weight of the deep water of the Caribbean Sea.

The frequency of earthquakes in Japan, in regions now non-volcanic, has been alluded to in the text. On July 11 a shock was felt in Tokio, the capital, but did no damage. Two weeks after a severe one occurred in Nagoaki, lasting five seconds, injuring several persons, and doing great damage to porcelain shops and dwelling-houses.

June 9: The town of Vernome, in Turkestan, Asiatic Russia, was almost entirely destroyed, and nearly one thousand people buried in the ruins. Many officials were injured; the shocks continued at intervals for several days; the inhabitants fled panic-stricken to the open country. Several surrounding towns were demolished by subsequent shocks, with great loss of life. An extensive region was disturbed, and the multiplicity of the diminishing waves is naturally explained by the gradual settlement of the displaced strata to a state of rest.

The Mediterranean basin has been frequently disturbed since May 29, when a violent shock was experienced at Tesi; felt also at Ancona.

July 18: At Malta, Cairo, Ismailia, and Alexandria, considerable damage was done, especially to the Egyptian mosques.

November 29: At Oran, Algiers, a distinct shock was felt in the afternoon. Many others might be noticed, but these are enough to recall the statement that earthquakes occur all over the globe, in regions non-volcanic as well as volcanic, at all seasons of the year, and at all times of the day, furnishing additional testimony that they are of geologic origin.

SUBSIDENCE — *June* 6: Half the new quays at Zug, Switzerland, fell into the lake, carrying with them forty houses, a

crowded inn, and the large hotel Zurich, drowning at least one hundred persons, who were engulfed while they slept. For several days crevices had been noticed in the stone work of the quay; the water in front was seen to bubble in the afternoon, and suddenly eight feet of the structure fell into the lake; after a short interval another slip occurred, and other houses and the landing stage were precipitated into the water. Boats going to the rescue were sucked into the abyss, and did not reappear. Toward night the land-slips began again, and houses, carts filled with valuables, and the hotel and café, were engulfed. At least four hundred and fifty feet of the shore vanished beneath the waters. The last slip occurred at eleven P. M., carrying away several houses. The loss of life and property was considerable. It is said that a similar disaster occurred there in 1433, when one hundred and sixty persons were drowned.

This recalls many similar catastrophes, and, on a small scale, is a specimen of the subsidences noticed in this book, arising from geological displacements of the earth's crust, accompanied, when of great magnitude, by earthquakes. In this case, from secular changes of the surface, a previous sinking had disturbed the strata; these remained at rest for four and a half centuries; then, stress from the further shrinking brought on a displacement in a line of weakness, rendered more liable to fall in by the great weight of the water in the lake. Though without volcanic or earthquake phenomena, it was in miniature a reproduction of the larger catastrophes which it has been the object of these pages to collect and explain, by a simple, ever-acting, and world-wide cause, namely, the shrinking of the crust, and consequent geologic displacements.

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AN ERUPTION OF VESUVIUS.